Transformative Modular Textile Design

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Abstract

This paper presents an interdisciplinary hybrid design that explores boundaries between mathematics, art, fashion and textile design using modular systems of materials based on geometric shapes. The intention behind this work is to encourage user participation in the design process through interactive and playful experiences using modular designs.

Introduction

Modular systems embrace the concept of "minimum inventory and maximum diversity," a model closely associated with architecture, engineering and the sciences. The system is subdivided into a number of standardized units (modules) that can be independently combined in a variety of configurations to drive multiple functions or create different structural forms [1]. Modularity, in the context of design, refers to the degree to which a product's components may be reconfigured, removed and/or added and the rules that enable or prohibit this [2]. The textile systems discussed within this paper utilize the principles of modularity in order to combine the advantages of standardization with the benefits of flexible, customizable and co-creative products, allowing the opportunity for individual personalization.

Inspired by fundamental geometric structure and patterns of growth in nature, concepts of symmetry and tessellations were explored in the creation of modular patterns and shapes. Utilizing knowledge of these geometric principles to support the creative process, a system of modular interlocking shapes was developed for practical application in textile and fashion design. These modular pieces, which can be combined or taken apart at the will of the user, allow product value to be co-created by both designer and consumer as part of a unique experience. The design outcomes are used to explore a practice that encourages the end-user to participate in design process through a flexible approach to the creation and transformation of various textile products.

Modularity in Design

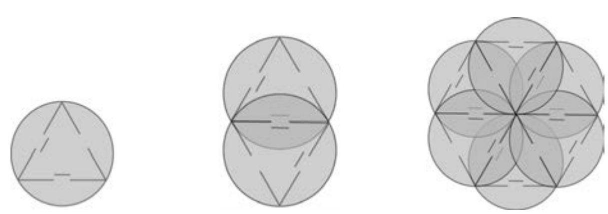
Historically the module was used primarily as a standard unit of measurement for proportioning in classical architecture, as described by Roman author and architect Vitruvius [3]. With twentieth century advancements in construction techniques, manufacturing and technology, modularity in the arts has developed not only as a tool for measurement but as the use of standardized units that physically combine with each other to form larger structures. In recent years there has been a growing interest in the principles of modularity in the disciplines of industrial design, fashion and textiles due to benefits such as ease of assembly/disassembly, customization, and cost effectiveness. Modular products provide flexibility and a wide variety of novel and versatile design outcomes that have the ability to grow and change easily without affecting the rest of the system. Notable examples of contemporary designers exploring the theme of modularity include Balgooi and Soepboer [4] and Rosenfeld [5].

Balgooi and Soepboer's modular clothing series, "Fragment Textiles" (2009) enables the user to become involved in customizing the design of the garment. Adopting a cradle-to-cradle approach, their objective was to create a system of fashion that was not just efficient but essentially waste free. In collaboration with Soepboer, Balgooi developed two modular fabric tiles based on square and star-shaped units, which could be combined to create larger fabrics that are completely reconfigurable in both color and form [4]. Rosenfeld's "Modular Series" is a distinctive fusion of mathematics, fashion and craft. An enthusiast of the use of geometric principles in her designs, Rosenfeld's pieces are based on more complex modules that can be divided into two types of component: basic units that form a repeating modular tessellation, to create lengths of fabric, and special units that interlock where seams would normally be positioned, allowing these areas to be structured and reconfigured with ease. In a similar arrangement as used in Soepboer and Balgooi's system, each module contains two tabs and two slots enabling it to interconnect with all of the surrounding modules [5].

An important strategy for many designers employing the principles of modularity is that of eco-efficiency in production and embodied emphatic experience in product consumption. Modular design enables the creation of products with a second "life" through its capacity to reinvent and reconfigure a product through use of a flexible core with adaptable and removable sections, which allow growth and change over time. The modular designs described above are characterized by their co-creative nature and their ability to be personalized to meet the needs of the user. This flexibility in design is created through a structural order founded on the principles of symmetry, tessellations and the adaptation of geometric shapes [6]. Each module takes the form of a tile that can be combined in a variety of ways in order to create the tessellating modular design. Therefore, in order to facilitate modularity in design, a mathematical appreciation of geometric structure and form is essential.

Exploring Modular Shapes

Initial exploration of a modular system for textiles began with the adaptation of polygons that comprise the regular tessellations of the plane. The modular unit shown in Figure 1 was developed from an equilateral triangle inscribed within a circle. The triangular region forms the underlying structural tessellation while the three regions created by the circumscribed circle form tabs. Carefully positioned slots at two edges of the triangle enable the tab of another module to be threaded through to interlock. Combining two of these triangular modules creates a rhombic unit and interlocking three of these rhombi (or six of the individual triangular modules) create a hexagonal unit as shown in Figure 1. When two or more triangular modules interlock, the overlapping tabs at each shared edge form an ellipse that generates a second layer of fabric creating a rich surface texture.



a) b) c)

Figure 1: *Modular series based on equilateral triangles showing a) the triangular module; b) two interlocking modules forming a rhombic unit; c) six interlocking modules forming a hexagonal unit*

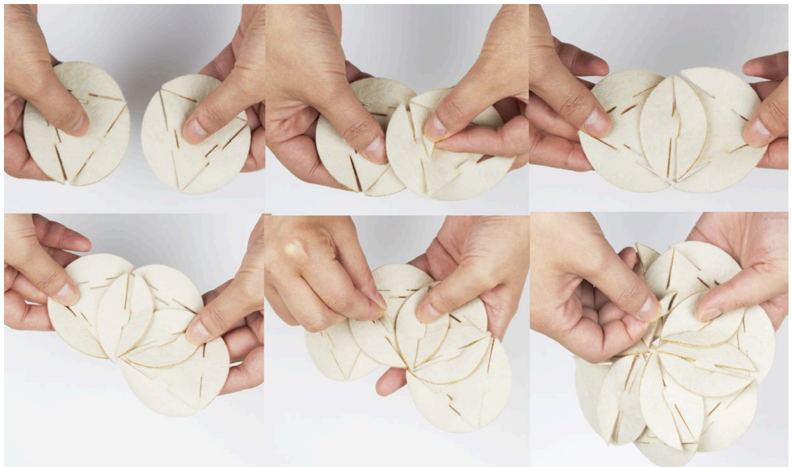


Figure 2: *Process for interlocking modular units*

Figure 2 illustrates the interlocking process that enables the extension of the modular structure. As the each edge of the triangular module is alike, there are a number of different ways in which overlapping ellipses can be layered to enable larger regions of the pattern to display different symmetries through simple manipulation of the order in which the tabs overlap. This feature becomes more prominent when a number of colored modules are used within the design. Triangular modules were assembled into the regular tessellation shown in Figure 3. On completion of the structure, the original shape has replicated itself numerous times and the fabric has become a complex design that has morphed from the original simple shapes.

Figure 3: *Modular tessellation based on the equilateral triangle*

Based on the evolution of the primary modular structure from the equilateral triangle shown in Figures 1 and 2, second-generation rhombic and hexagonal modules were developed. The rhombic module (Figure 4a) was developed from the unit formed by two interlocking triangles and the hexagonal module was derived from six interconnecting triangular shapes (Figure 4b). The development of subsequent modules from the original triangular unit maintained polygons with equal length sides in order to facilitate their interconnection. The series of modules was further extended to include other regular polygons such as the square, octagon and dodecagon.

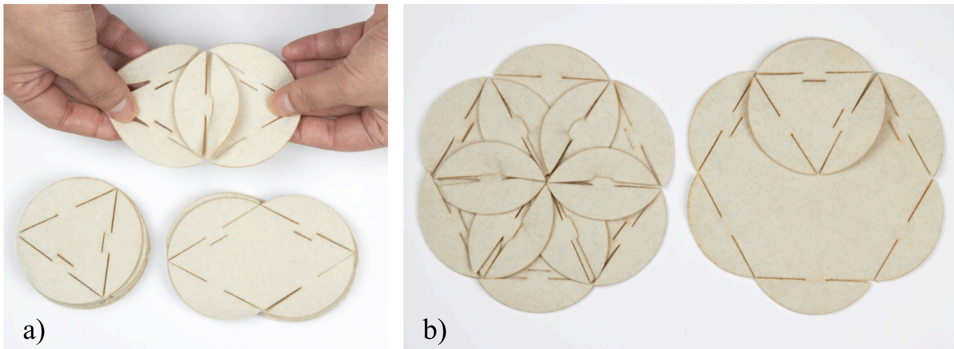


Figure 4: *Development of a) the rhombic module and b) the hexagonal module from the primary triangular unit*

A third generation of modules possessing sides twice the length of the original triangular unit were subsequently created with each side possessing two tabs, as illustrated in Figure 5. This enabled these large modules to combine with the smaller units within the series. Maintaining equal length sides and/or equal tab sizes within the module series enables an infinite number of non-uniform periodic tessellations to be created through combinations of modules of different shapes and scales, as shown in Figure 6.

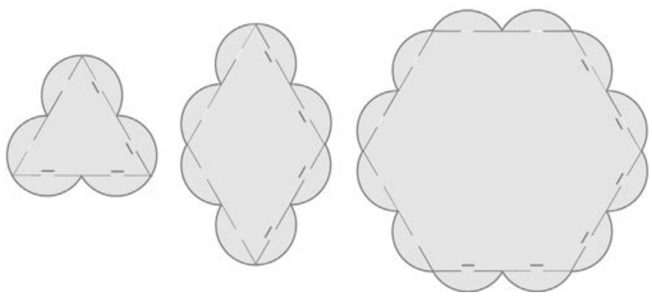


Figure 5: *Third-generation modules displaying two interlocking tabs on each side*

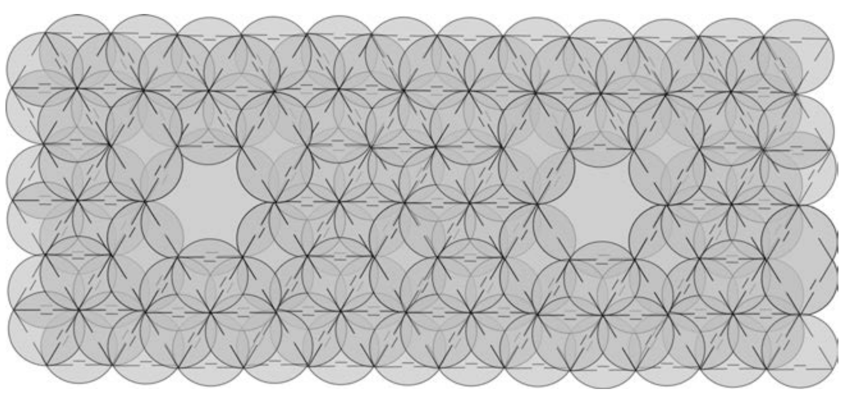


Figure 6: *Non-uniform periodic tessellation created using triangular, rhombic and hexagonal modules*

Transformative Modular Textiles

Additional series of modules were developed using the interlocking system outlined above. One such series was developed from the equilateral triangle module inscribed within a hexagon, as shown in Figure 7a**.** This series varies from that discussed above as the tabs created from the hexagon form isosceles triangles equal to one-third of the area of the triangle. When modules are interlocked, adjacent tabs form a precisely corresponding second layer of fabric tessellation, rather than overlapping layers as seen in the previous modular series. This simple modular design is particularly visually effective when combined with modules of varying color. The rhombic unit in Figure 7b is derived from two interlocked triangular modules in a similar manner as previously discussed. It can be seen from the illustration in Figure 7c, that the second layer of the tessellation produced by interlocking tabs forms a linear pattern above the rhombic framework.

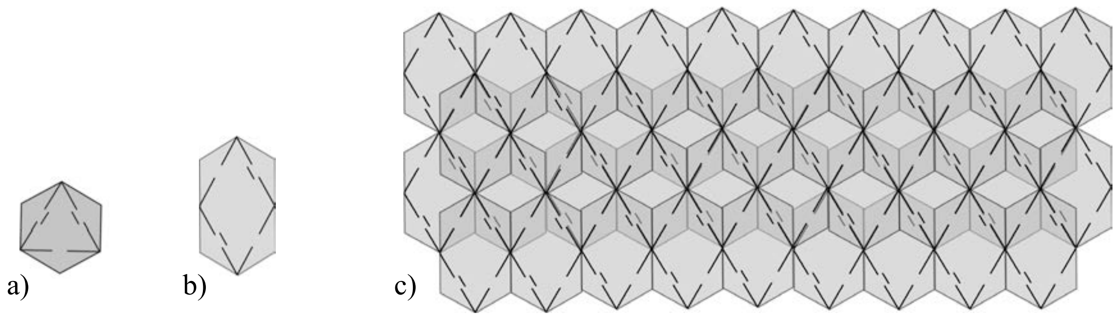


Figure 7: *Modular series showing a) the initial triangular module b) the derivative rhombic module and c) the tessellation of the rhombic module*

Further development of the modular structures incorporated the principles of self-similarity through the combination modules of varying scales. These developments resulted in a significant increase in the complexity of the fabrics. The tessellation shown in Figure 8 was created using 36 small triangular modules and eight large triangular modules. The large module was developed with two identically sized tabs on each side enabling it to interconnect with the small unit. This concept was extended again through incorporating tabs of differing scales within the same modular unit (Figure 9a). This fourth generation module enabled a single module to be interconnected with a variety of units of different sizes to produce a self-similar tessellating structure, as shown in Figure 9c.

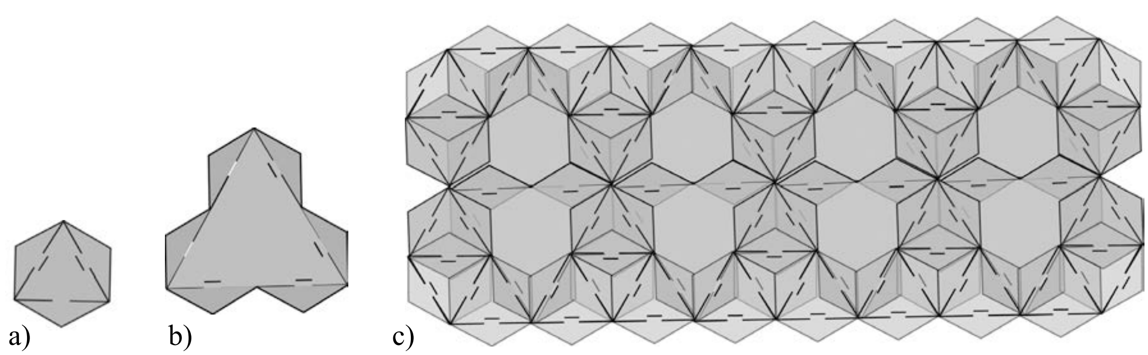


Figure 8: *Development of the modular series showing a) the initial triangular module b) the derivative larger module and c) a tessellation incorporating the two sizes of module*

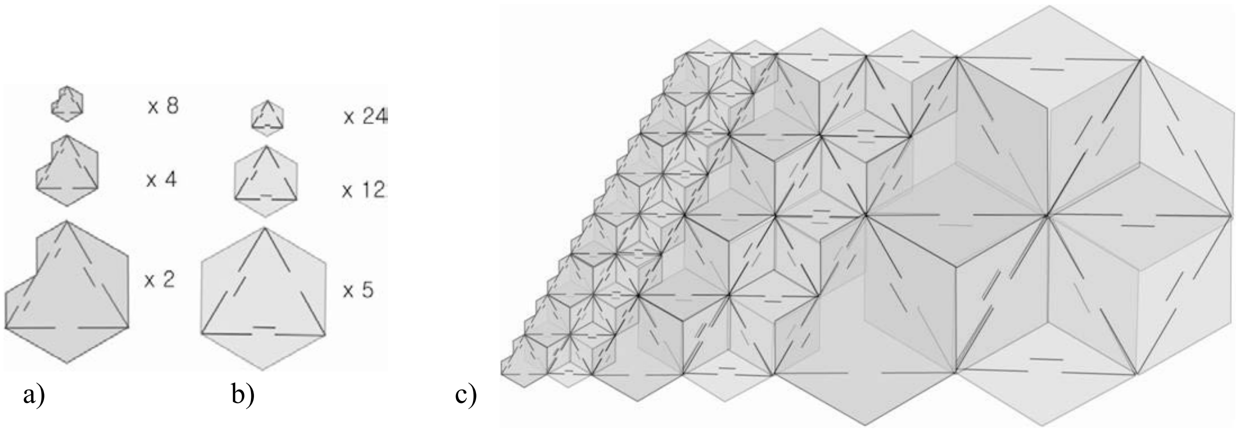


Figure 9: *Development of the modular series showing a) fourth-generation modules b) first generation modules and c) one possible self-similar tessellation created from these units*

Further experimentation considered the addition of differently colored modules that added a further textural quality when combined. A variety of materials were explored for use in the modular system considering their suitability to potential end uses in both interior and fashion design. These included leather, bonded e-leather with cashmere, wool felt, and wood, combined with laser cutting and printing techniques, such as sublimation printing on wood, acid printing on wool felt and laser etching on leather. Examples of a wool felt modular design for fashion and interior accessories are shown in Figure 10.

Figure 10: *Eunsuk Hur, Transformative Modular Textile Design, 2009*

The modular system presented above allows the user freedom to arrange and interchange the fabric modules enabling the shape be grown spontaneously, leading to a tessellating organic structure. The system is extremely versatile with possible configurations ranging from simple arrangements with a small number of repeating units to modules of different shapes and sizes combined to create complex large-scale designs. The system was originally developed to facilitate participatory co-design practices, as discussed below, but also offers great potential for the development into an educational tool to aid the teaching of geometry.

User Engagement with Transformative Design

User engagement in the design process is built on the idea that the end user is entitled to be involved in determining a product's design [7]. This concept of co-design (co-creation in design) incorporates the principles of inclusivity, collaboration, participation and community in a user-centered design practice. Designers use this methodology to develop a partnership with a product or service's end users. This participatory approach provides the opportunity to engage the user, potentially creating a deeper understanding of the design process through the user's ability to create their own styles and experience alternative concepts and approaches. Modularity presents an ideal platform for co-design practices, offering the benefits of flexible, customizable products, and increased value-in-use, which may extend a product's life span through experiential consumption.

A pilot workshop to explore participatory practices through transformative modular design took place at a central London 'pop-up' shop over a five-day period in March 2010. The event was a collaboration between designers aiming to develop a new dialogue in design through participatory activity. The aim of the workshop was to investigate user engagement in a "learning by doing" process, alongside a designer. Using the modular toolkits developed from the system outlined above, participants were guided through the step-by-step creation of products and were given the freedom to decide the design configuration, material, size, quantity, colour and finishing. Each set of textile pieces could then be rearranged to transform one item into various other hybrid designs. Participants produced their own unique work and shared their ideas and modular designs through play. This community level co-design extends collaborative design practices by enabling groups of people to share their experiences and knowledge actively within a social context.

Figure 11: *Outcomes of the user engagement workshop, 2010*

The interlocking modular structure allowed endless possibilities for participants to create fabric designs of varying scales with the simple design system transforming as the user combined modules and explored the materials. Participant feedback from the workshop indicated a preference towards large-scale modules when "building" clothing, and that the creation of fabrics using the smaller modules was considered to be very time consuming. The practicality of the construction method requires approximately one hour to produce a dress, 30 minutes to produce a scarf and ten minutes to produce a hair accessory. However, these times vary depending on the complexity of the design, the individual's confidence and experience level, and the scale of the modular units selected. Figure 11 illustrates a number of outcomes from the workshop.

In Conclusion

The modular textile system described within this paper was based on simple polygons and tessellating shapes. However, the mathematics of this modular system allows these shapes to be transformed into sophisticated textile designs for fashion or interior decoration. Unlike traditional textile designs there is no sewing as the textile and the garment are created simultaneously and the modular structure allows infinite design possibilities based on variations in the underlying tessellation. Modular systems of textiles enable the creation of products with a second "life" through the system's capacity for reinvention. Individual modules can be rearranged in order to create different patterns, or colorways, to reconfigure the product's structure (e.g. change a "hemline" or create an entirely different garment), or for practical reasons when an area becomes damaged or stained.

Compared with the work of Balgooi and Soepboer [4] and Rosenfeld [5], the modular system presented above has considerably extended the number units of different scales that may be used within a single design. A range of different materials has also been explored (although the durability of different materials requires further evaluation), alongside further investigation into the possibilities for user participation. Looking to the future, it is likely that new modes of design practice will involve collaboration across disciplines and partnerships with consumers, engaging the designer and user beyond existing boundaries, and reinventing the current approaches to design. In addition to traditional notions of social, economic and environmental sustainability, personalized and transformative products offer the possibility for emotionally durable, multifunctional design that has the potential to reduce consumption.

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