GLOBAL ACADEMIC RESEARCH INSTITUTE

COLOMBO, SRI LANKA

GARI International Journal of Multidisciplinary Research

ISSN 2659-2193

Volume: 07 | Issue: 04

On 31st December 2021

http://www.research.lk

Author: Shahab Jalalimanesh, Lin Xun

School of Design, Shanghai Jiao Tong University, China

GARI Publisher | Textile Design | Volume: 07 | Issue: 04

Article ID: IN/GARI/ICATFD/2021/202 | Pages: 35-48 (14)

ISSN 2659-2193 | Edit: GARI Editorial Team

Received: 30.09.2021 | Publish: 31.12.2021

APPLYING MATHEMATICAL MOTIF-BASE-PATTERNS INTO TEXTILE SURFACES: CULTURAL MEANING, AESTHETIC VALUES, MARKETING EFFECTIVENESS

Shahab Jalalimanesh, Lin Xun

School of Design, Shanghai Jiao Tong University, China

ABSTRACT

Textile is one of the earliest human production and symbol of civilization. Textile design is an art form which associates with practicality and aesthetics. The main elements used for decorating textile surfaces are motifs and patterns. Mathematical ratios are an integral part of pattern design which are applied in various patterns. Mathematical-based patterns also draw much attention in textile design. However, since applying precise mathematical patterns is not easy, designers often set elements in non-mathematical methods. The presented paper proposed quad-spiral floral structures to create textile patterns. Python programming language is used for accurately tiling motifs into squares based on the Fibonacci numbers sequence. Specifically stylized floral motifs that appeared on textiles surfaces during the late Ming dynasty in China are extracted and restructured for creating patterns. New patterns are formed and extended by mirroring techniques to demonstrate the final prototypes based on mathematical number sequences and reorganized motifs. Textile experts evaluate the usability and feasibility of the presented designs, and the profitability and marketing effectiveness of final prototypes are positively approved.

Keywords: Mathematical Design, Textile Design, User Study, Innovative Design

INTRODUCTION

One of the most demanding worldwide markets belongs to the textile industry, which has been reported as the second-largest global business after the food industry. Each year around 10 percent of the global energy supply has consumed for providing approximately 99 million tons of textiles around the world (Paras et al., 2018), which indicates the importance of this industry. Consequently, in such a big industry, the competition for catching the consumers' attention is fierce, and companies attempt to keep consumers satisfied by various methods, including purposive marketing, innovative technologies, and creative surface design. Nowadays, design methods and procedures are affected or entirely changed thanks to computers and machinery developments. For example, vector base soft-wares help designers to create and extend patterns accurately and faster. This increasing speed and accurateness is critical to fulfilling the needs of the textiles growing market

Patterns and motifs are the aesthetic qualities that were designed and developed to elaborate textile surfaces from ancient times to the present. According to the Surface Design Association (SDA), the textile surface design includes coloring, patterning, or forming fibers by techniques such as dyeing, printing, painting, embellishing, or quilting (Miles & Beattie, 2011). Motifs are formed elements used for decorating textile surfaces and can be repeated in a specific structure to shape a pattern

(Baldvinsdóttir, 2013). Patterns and motifs are generated by gestalt aesthetics, include points, lines, forms, colors, and textures with several methods and supplies (Homlong, 2006) to decorating a textile surface and define relations between viewer and pattern spatial structure (Kristensen Johnstone, 2017). Ancient motifs can be considered as inspiration sources for designers to create meaningful patterns enriched with cultural roots. During the Ming dynasty, the social base for art grown much broader, and craftsmanship soared to new levels in China (Hay, n.d.; Yin, 2020). The structure of stylized floral motifs that appeared on textiles at that time reached an extreme balance of bilateral symmetry. These advanced aesthetic achievements persuade us to reuse them for creating patterns in this study.

Leonardo Pisano Bigollo, known as Fibonacci, is an admirable Italian mathematician celebrated for the mathematical idea famed as the Fibonacci numbers sequence. The pattern created based on this numerical sequence is interestingly embedded in various phenomena, including mathematics patterns and forms in art and nature (Reich, 2012). Fibonacci learned about the Indo-Arabic numeration system and computational system when studying in Algeria and became familiar with the Persian polymath Al-Khwarizmi's works in mathematics, algebra, astronomy, and geography. When Fibonacci returned to Italy around 1202, he published his founding in a book called Liber Abaci (Chavan & Suryawanshi, 2020). Fibonacci present the following question:

If we locate a pair of rabbits (one male and one female) in a bounded space, if we assumed that every month each pair of rabbits produces extra pair with no fatality, and that rabbits become mature in two months after their birth, how many rabbits will be produced in a year? (Reich, 2012)

In Liber Abaci, Fibonacci introduced a hypothetical increasing number of rabbits based on idealized assumption. He indicates rabbits' population increased from 1 to 2 to 3 to 5 to 8 to 13 to 21 pairs and continued by the sum of the last two numbers each month and can extend infinitely.

Therefore, if we assume we have one pair of rabbits (male and female) at the beginning of the first month, it will take a month to breed another pair. Then in the third month, we have two pairs of rabbits, and in four-month three pairs. According to Table 1, if this sequence continued for 12 months at the end of the year, we have 144 pairs of rabbits. According to the mathematical term $f_n=f_{n-1}+f_{n-2}$ the obtained Fibonacci number sequence is 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, etc.

Table 1: Represent the total number of pair rabbits in a whole year

Month	**Infant Rabbits**	**Mature Rabbits**	**Total**
1st Month	1	0	1
2nd Month	0	1	1
3rd Month	1	1	2
4th Month	1	2	3
5th Month	2	3	5

6th Month	3	5	8
7th Month	5	8	13
8th Month	8	13	21
9th Month	13	21	34
10th Month	21	34	55
11th Month	34	55	89
12th Month	55	89	144

In recent years, researchers began to work on the Fibonacci number sequence in various filed of studies including the spiral arrangements that appeared in nature, aesthetic assessments based on mathematical ratios (Abrouk et al., 2021), fractal patterns for antennas (Shookooh et al., 2020), engineering and science (Chavan & Suryawanshi, 2020), fashion and accessories design (Ilieva et al., 2021) wireless sensor network production (Yacoab et al., 2019). However, this study's core objective is to create textile patterns based on the Fibonacci numbers sequence by reusing ancient Chinese floral motifs extracted from the Ming dynasty textiles, hoping that it may help develop a more appreciation of the mathematical ratios in textile pattern design.

The remainder of this paper is divided into four sections. Section 2 aimed to introduce related works, including the Fibonacci golden ratio and art-related works. Section 3 defines methods for extracting and coloring motifs from historic textiles and applying them in spiral forms based on the Fibonacci sequence. Section 4 presented final textile pattern prototypes made by repeating spirals and discuss results. This paper will end with a conclusion in section 5.

LITERATURE REVIEW

This section aims to introduce and review the Fibonacci and golden ratios works and how they are related and used in science, nature, fashion, and textile design.

Golden ratio

The golden ratio, also known as golden proportion, divine proportion, or mean ratio (Markowsky, 1992), is an irrational number characterized by the Greek letter phi (symbol: φ). Phi (φ) is an approximate value equal to 1.6180339887. Any two number of the Fibonacci sequence ratio is approximately equal to 1.618, which indicate the correlation of the Fibonacci numbers and golden ratio (Omotehinwa & Ramon, 2013). The golden ratio is made base on unique mathematical principles. Therefore, if a line gets divided to a certain extent that the whole length ratio (a+b) to the longer proportion length (b) occur to be equal to the ratio of the longer proportion length (a) to the shorter proportion length (a), the resultant ratio is equal to phi (φ).

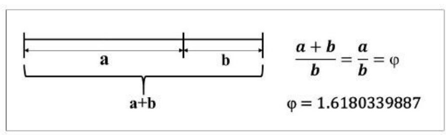

Figure 1: Golden ratio and Phi

Golden ratios have been applied in art and architecture from 2500 years ago (Kuliš & Hodžić, 2020). It can be traced in everything and everywhere (Watson, 2017) and get involved with various scientific subjects includes psychology and psychological aesthetic (Vico-Prieto et al., 2016), physic and mathematic (Sherbon, 2018), biology (Wille, 2012), economic systems (Brazhnikov, 2021), fashion, textile and accessories (Ilieva et al., 2021), and many other subjects.

Golden ratio and the Fibonacci number sequence connection

It is not confidently clear whether Fibonacci himself was aware of the ratio relation of the sequence numbers he discovered or not (Kuliš & Hodžić, 2020). However, the fascinating feature of the Fibonacci numbers will emerge when one number gets divided by the previous one in the sequence, which gets outcomes that are extremely close to one another (Kelley, 2012). The exciting part is where that the result of dividing

Fibonacci numbers is almost equal to phi ($\varphi = \frac{1+\sqrt{5}}{2}$ =1.618) mainly from the 14th number in the sequence as it is shown in Error! Reference source not found. or in another word $\varphi \approx \frac{Fn+1}{Fn}$ (Chavan & Suryawanshi, 2020; Omotehinwa & Ramon, 2013) which indicates the connection of the golden ratio and the Fibonacci number sequence in mathematical terms.

Table 2: Result of dividing the numbers to previous ones in the Fibonacci sequence

No.	$\frac{f_n+1}{f_n} \approx \mathbf{1.6180339887}$	**No.**	$\frac{f_n+1}{f_n} \approx \mathbf{1.6180339887}$
1	$\frac{1}{1} = 1.000000000000000$	14	$\frac{987}{610} = 1.618032786855245$
2	$\frac{2}{1} = 2.000000000000000$	15	$\frac{1597}{987} = 1.618034447821682$
3	$\frac{3}{2} = 1.500000000000000$	16	$\frac{2584}{1597} = 1.618033813400125$
4	$\frac{8}{5} = 1.600000000000000$	17	$\frac{4181}{2584} = 1.618034055727554$
5	$\frac{13}{8} = 1.625000000000000$	18	$\frac{6765}{4181} = 1.618033963166707$
6	$\frac{21}{13} = 1.6153846153846115$	19	$\frac{10946}{6765} = 1.618033998521803$
7	$\frac{34}{21} = 1.619047619047619$	20	$\frac{17711}{10946} = 1.618033985017358$
8	$\frac{55}{34} = 1.617647058823529$	21	$\frac{28657}{17711} = 1.618033990175597$
9	$\frac{89}{55} = 1.618181818181818$	22	$\frac{46363}{28657} = 1.617859510765258$
10	$\frac{144}{89} = 1.617977528089888$	23	$\frac{75025}{46363} = 1.618208485214503$
11	$\frac{233}{144} = 1.618055555555556$	24	$\frac{121393}{75025} = 1.618033988670443$
12	$\frac{377}{233} = 1.618025751072961$	25	$\frac{196418}{121393} = 1.618033988780243$
13	$\frac{610}{377} = 1.618037135278515$	26	$\frac{317811}{196418} = 1.618033988738303$

Golden rectangle and Fibonacci spiral

The golden rectangle is incredibly well-known and the most common geometric figure used dominantly in art, design, and architecture since it has the most satisfying shape to human eyes (Desai, 2017). In a rectangle, if a square section that has sides equal to the short size of the rectangle gets separated, and still the remaining portion has the same side length ratio as the original rectangle, the outcome will be called a golden rectangle. Drew on Figure 2, the golden rectangle has side lengths as a and b and 0 < b < a, therefore:

$$\frac{a+b}{b} = \frac{a}{b} = \frac{1+\sqrt{5}}{2} = \varphi = 1.618$$

$$\varphi \approx \frac{f_n+1}{f_n}$$

Spirals are created based on a state of growth called "self-similarity" or scaling and tend to develop in scope without any changes in the shape (Reich, 2012). The logarithmic mathematical of golden spirals are essential in art and architecture design and have a central role in many biological systems growths and structure (Watson, 2017). Golden spiral existed in various interesting positions in nature, such as seeds of sunflower, pine cane, in the shape of a nautilus shell, pineapple, and flower petals (Omotehinwa & Ramon, 2013). Formulate on a golden rectangle, the Fibonacci spirals will be created. It is formed on a quarter (1⁄4) of a circle tanged to the interior of each square whose sizes correspond to the Fibonacci sequence in the golden rectangle (Duan, 2019). According to Figure 2, if we spot angle X as the center and drawing a quarter circle through the corners of each square, the Fibonacci spiral will be shaped.

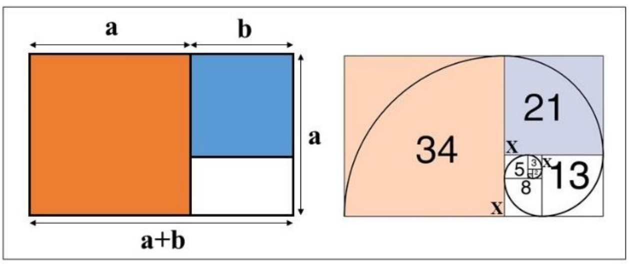

Figure 2: Golden rectangle and Fibonacci spiral

Fibonacci series in fashion and textile design

In some cases, mathematics can be considered art, particularly where artists use it to form aesthetic shapes or ideas. Thanks to new technology developments, art and mathematic mixed together, and more designers aimed to bring the aesthetic laid behind mathematical formulas into visual forms and patterns. Zlatina Kazlacheva and Julieta Ilieva present models for the front sides of garments patterns based on tiling golden spirals, golden rectangle, and the Fibonacci series and generating textile pattern relative to the Fibonacci rose (Kazlacheva & Ilieva, 2016). Somina Benali designed strips with geometric shapes to decorate textiles surfaces using golden spirals and create them according to the first seven Fibonacci series (Benali, 2020). Many artists and researchers have begun to introduce the divine proportions and golden spirals based on the Fibonacci numbers sequence in the art and design field. However, the lack of practical works in this direction, especially among fashion and textile designers, is still noticeable.

METHODS AND APPROACH

This part of the study is presented in three phases:

- Extracting stylized floral motifs from ancient textiles and reorganized them.
- We colored the prepared motifs with two different color palettes to inspire new patterns.
- We generate textile patterns based on the Fibonacci series by applying several Fibonacci sequences with tiling squares to shape a quad spiral pattern made by prepared floral motifs.

These tasks demonstrate various attempts through design methods and combine ideas to form a new mathematical symmetry pattern for decorating textiles surfaces. In this study case, the point of interest is to creating spirals based on the mathematical forms as the foundation of patterns. These spirals are generated in golden rectangles divided by squares scaled according to the Fibonacci number sequence. This study intends to present aesthetic patterns that can catch the attention of textiles consumers and experts (designers and sellers). A questionnaire regarding the final prototypes was prepared and handed to the recruit participants to analyze their opinions toward the presented patterns to fulfill this purpose. The results have been presented in the next section.

Floral motifs preparation

Building blocks or units reputation creating motifs, and by repeating motifs in particular structures, patterns are generated. Because of the manufacturing methods, patterns can automatically be repeated again and again to elaborating textile surfaces. Motifs and patterns repeated by several methods include one on top of another, half-drop repeats, tile repeats, and mirroring or reflecting elements. All of these design types are generated according to geometric and symmetry principles. Flowers in many cultures are the symbol of nature, delicateness, happiness, tenderness, and love. Floral motifs with different forms, colors, and postures are widely used in textiles design, carpet design, architecture, and many other arts. Designers and artists create geometric and symmetric stylized flowers to provide strong flexibility and wide-fitting forms for applying them into different shapes and places.

As mentioned earlier, Chinese stylized flower design developed throughout a long history and reached a peak by the Ming dynasty. Lotus and peach blossoms are the most common flower motifs used in ancient textiles. Lotus is the central flower in Chinese art and symbol of Buddhism, meaning summer, longevity, marriage, and fertility, and peach blossom represent springtime and immortality. Error! Reference source not found. shown three fragments of Chinese textiles used as sutras cover belongs to the late Ming dynasty (16th century) provided by The Met museum as a part of The Mets Open Access program. Fragment (a) is a 36.2 × 12.7 cm woven textile with stylized lotus flower decoration on its surface. Fragments (b) and (c) are silk satin woven textiles with the same size as fragment (a) with floral scrolls picturing stylized peach blossoms on the fragment (b) and stylized lotus on the fragment (c)

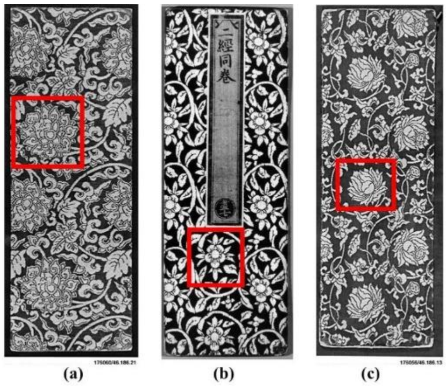

Figure 3: Three textile fragments. (a): Sutra Cover with Floral Scroll, accession number: 46.186.21 Metmuseum.org. (b): Sutra Cover with Floral Scroll, accession number: 46.186.20 Metmuseum.org. (c): Sutra Cover with Lotus Scroll, accession number: 46.186.13 Metmuseum.org

After reviewing the available ancient textile fragments with floral designs exhibited by The Met museum, as illustrated in Figure 3, three stylized flower motifs are separated for this study. However, because of the textiles flexibility, aging, and the practical usage of textiles, the stylized motif's symmetries are a little deformed, and structural reorganization is needed. To this end, initially, a half-hand-sketch draw of each motif has been prepared. Afterward, for having a more accurate form in all dimensions, AutoCAD software is used to create motifs more efficiently. The results are presented in Figure 4.

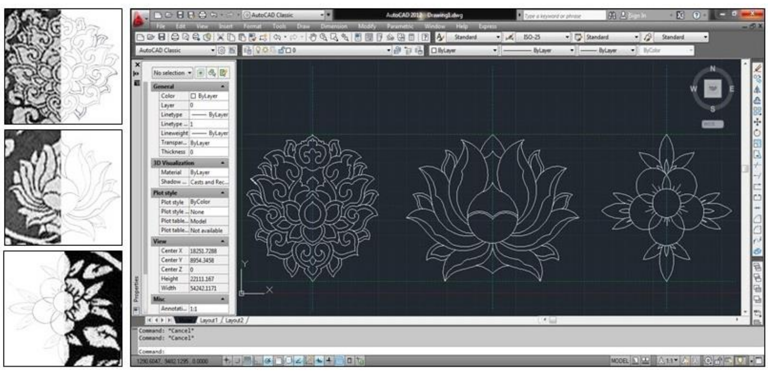

Figure 4: Restructured floral motifs

Motifs coloring

Human eyes can separate and seen more than 10 million colors under normal lighting conditions. Many research investigates color developments and color theories, and many scientists worked hard to understand color logics. The role of colors in the fashion and textile industries' success cannot be underestimated, and many institutes are founded to predicting color trends every year Pantone or Trendunion. Various methods and techniques are developed for coloring textiles, such as fiber dyeing, yarn dyeing, painting, and printing. Psychologically, colors have different effects on human emotions. For example, red is exciting while green is calming. Research has revealed that different tones of one color have different psychological effects, like pale and dark versions of one color representing reverse effects. Moreover, colors have diverse meanings and usage in different cultures and during different periods.

We tried to use the most similar colors to the Ming dynasty textiles color. Colors are analyzed and extracted with Adobe Color online software from colorful pictures of two Chinese textiles from the 16th and 17th centuries provided by The Met museum. As shown in Figure 5 to make the redesigned motifs distinguishable in textile patterns generated in the further sections of this study, two different palettes are created according to the extracted colors. One palette is for the red and yellow tonalities, and another one is for the blue and green tonalities.

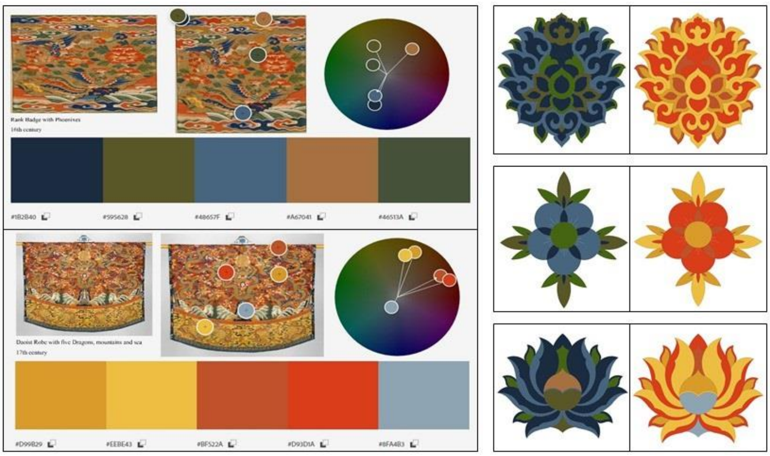

Figure 5: colored motifs according to colors used in the Rank Badge with two Phoenix with accession number 36.65.31 themetmuseum.org, and the Daoist Robe with accession number 43.144 themetmuseum.org.

Tiling motifs corresponding to the Fibonacci numbers sequence

Using squares with side lengths corresponding to the Fibonacci numbers is a possible method for visualizing the Fibonacci sequence.

To this end, we start with creating a single square with side lengths 1×1 and then adding an additional square to one side of the square will result in a 2×1 rectangle. Next, by tiling another square of size 2×2 to one of the longest sides of the previous rectangle, another rectangle with size 3×2 will be generated. Finally, continuing this procedure by adding squares with side lengths corresponding to the Fibonacci numbers to the longest sides of the last rectangle, we will have several squares with side lengths of 1, 1, 2, 3, 5, 8, 13, and so on.

Two standard methods for creating the structure of tiling squares are available. One method is constantly circling the block as we decide where to put the next square, which concludes with a spiral pattern, as illustrated in Figure 2. The method that has been used in the presented study has shown on the left side of Figure 6. Once we are going to choose the location of the next square relative to the previous square, we will choose the upper side and the left side of the previous rectangle. According to what has been shown in Figure 6, a quad-spiral pattern will appear by rotating the rectangle around point A and coloring squares (Baird, 2009).

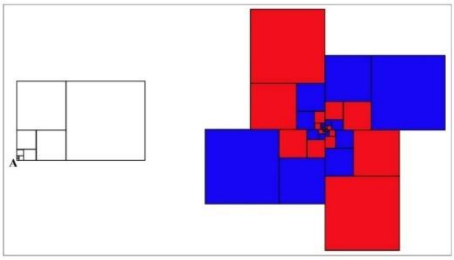

Figure 6: Quad spiral structure (Baird, 2009).

To tile motifs in a structure with dimensions and form of the quad-spiral, we need to find the precise center point of every square and match every motif with the center points of squares. In order to locate the center point of squares, we will start from the center of the smallest square in one of the rectangles. Since the side lengths of squares are based on the Fibonacci numbers, the center of other squares can be calculated respectively (Holden, 1975). Fibonacci numbers and the center of their corresponding square are presented in Table 3.

Table 3: Center of squares

i	f_i	Center
1	1	(0, 0)
2	1	(0, 1)
3	2	(1.5, 0.5)
4	3	(1, 3)
5	5	(5, 2)
6	8	(3.5, 8.5)
7	13	(14, 6)
8	21	(10, 23)
9	34	(37.5, 16.5)

The size of the squares which motifs are located inside them will specify the size of motifs. First, a base size for the smallest square has been chosen. Then the next squares' size will be calculated by multiplication of the Fibonacci numbers to the mentioned base size.

Ultimately, the python programming language and its NumPy package have been used for calculating motifs locations and setting them in their particular places. Also, the Matplotlip package has been used for the visualization of results. The outcome is illustrated in Figure 7.

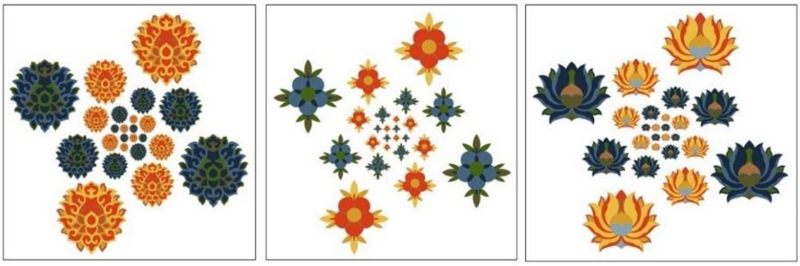

Figure 7: Floral quad-spirals with motifs tiling based on the Fibonacci sequence

Prototype evaluation

For measuring final prototype qualifications, various criteria's include aesthetic, composition, and color, are involved. Therefore, a test was conducted on 30 experts with at least one year of experience in fashion and textile design or textile marketing (wholesale and retail sellers). The results are presented in the next section.

DATA ANALYSIS

In studying textile surface designs, elements such as motifs, patterns, and color are the central principles. Patterns are created by repeating motifs in a specific structure and have the capability to repeat them again and again on textile surfaces. Patterns' shape and size may have the potential to change due to different methods of repeating. Colors used in pattern design for different purposes include psychological or emotional effects, attention-grabbing, and aesthetic decorations. Moreover, colors can be used for separating elements or clarifying portions in complex patterns.

Trends are changing as designers embrace technologies, materials, and methods. In the presented study, we restructure historical motifs and combined them with mathematical principles to generating new patterns. A quad-spiral structure made by the Fibonacci numbers sequence and golden ratio portions has been used for new patterns base structure. Motifs were tiling in the exact spot in structure using python programming language and visualized by the Matplotlib package. Two different color palette has used for identifying spirals in the patterns. As shown in Figure 8, the textile patterns are extended by mirroring techniques and can be used for various purposes. These patterns are capable of extending unlimitedly.

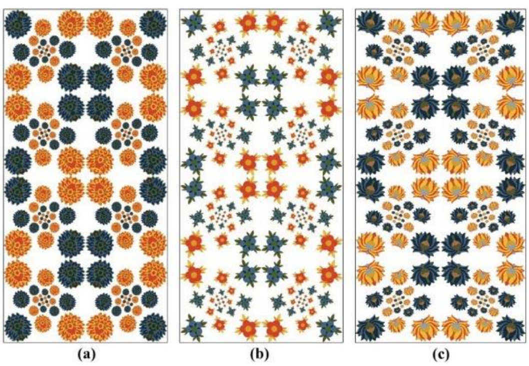

Figure 8: Final prototypes

We performed a study survey to compare the three final prototypes and evaluate their design feasibility and usability.

15 fashion and textile designers with university educational backgrounds and 15 textile sellers were recruited to participate in this study. The key prerequisite for each participant was having at least one year of related work experience. The bar chart in Figure 9 has shown that over half of the participants had 5 to 10 years of work experience. In addition, participants were asked not to use phones or computers to browse for information while partaking in the study.

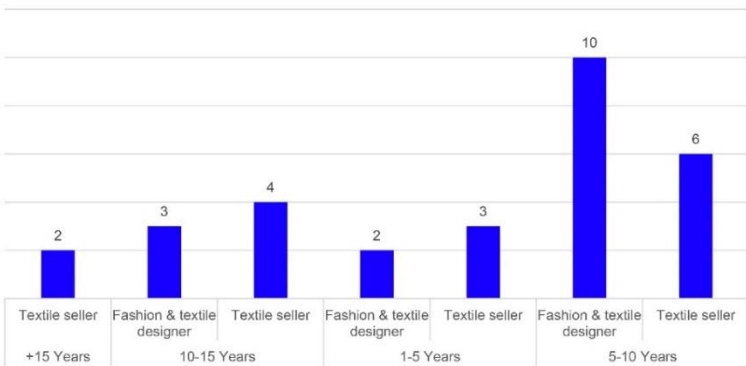

Figure 9: Participants occupation and years of experience

The three final prototypes (as illustrated in Figure 8) are prepared and presented to participants with a blank (white) background. This ensured that the background color or texture does not affect participants' opinions. Also, we asked participants to what extent they are familiar with mathematical terms in design works and the Fibonacci numbers sequence. As Figure 10 shows, most of our participants know a little or nothing about these concepts. Therefore, to avoid possible bias, we provide some initial information for those who know nothing about the Fibonacci sequence.

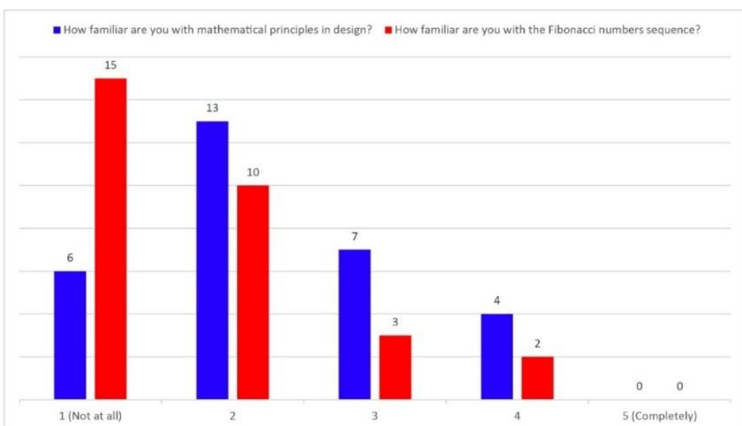

Figure 10: Participants knowledge of mathematical design and the Fibonacci concept

A total of 12 questions were used for the three final prototypes evaluation. In the questionnaire, we intend to investigate participants' opinions regarding the final prototypes by three types of questions. The first types of questions are asked to realize how much participants are interested in patterns and motifs creation methods. The second type of questions tried to understand to what extent participants agree that these design works are suitable for their customers or can be successful in the textile market. Finally, in the third type of questions, we tried to measure to what degree participants are satisfied with each prototype. The questionnaire used a five-point scale from 1 (completely disagree, very uninteresting, and very dissatisfied) to 5 (completely agree, very interesting, and very satisfied). Results are presented in Table 4.

Table 4: Questionnaire results

Inquiries	Mean	Std. Deviation	Median (range)
How interested are you in the following terms?			
Patterns production methods	4.57	0.73	5 (2-5)
Patterns eye-pleasing formation	4.47	0.78	5 (2-5)
Motifs shapes	4.3	0.99	5 (1-5)
Colors that used in patterns	4.1	0.96	4 (1-5)
How much do you agree or disagree with the following statements?			
Patterns are attention-grabbing for customers	4.43	0.9	5 (1-5)
Patterns are applicable for different purposes	4.47	0.9	5 (1-5)
Patterns can be economically profitable	4	0.91	4 (2-5)
Patterns are designed according to new trends in the market	4.23	0.77	4 (2-5)
How would you rate your overall satisfaction with these prototypes?			
Prototype (a) patterns design	4.27	0.78	4 (2-5)
Prototype (b) patterns design	4.53	0.78	5 (2-5)
Prototype (c) patterns design	4.43	0.82	5 (2-5)

The data of participants' responses are statistically analyzed with mean, median, standard deviation, and range. One sample t-test was used to analyze the statistical significance of results which shows all mean values are meaningfully higher than the neutral point. P-value < 0.05 was considered to be statistically significant.

Results indicate that experts are interested in production methods, pattern formation, motifs shapes, and colors. Particularly, pattern production methods and techniques were more attractive for experts. Also, according to the responses, patterns are applicable for different purposes, for example, dresses, T-shirts, and bags. Experts believe final prototypes have a good chance for acceptance by consumers. Prototype (b) was the experts' favorite pattern with a mean value of 4.53 and a median of 5.

CONCLUSION

Textile design is where aesthetics meet practicality, and a wide variety of activities is needed to improve our performance. The findings indicated the usability of applying mathematical terms into designs to create eye-pleasing textile patterns. In this study, we based the Fibonacci numbers sequence as a structure to forming floral patterns. Furthermore, by leveraging Chinese traditional artistry in our design, we reused stylized lotus and peach blossom motifs that embellished textiles during the Ming dynasty. Python programming language was used to precisely tile the motifs in a quad spiral framework and extended by mirroring techniques to make final prototypes. However, further studies are needed on the Fibonacci sequence in shaping patterns or other mathematical models as one of the design possibilities in future studies.

We encourage other designers to explore how to apply mathematical models to bring precision, consistency, and balance in design works. In the future, we will try to find appropriate methods to design symmetric backgrounds for patterns to set balance among different elements in a framework. The findings can serve as references for the textile producers and designers in the design of motifs and patterns.

REFERENCES

Abrouk, M., Harris, L., Rieder, E. A., & Waibel, J. S. (2021). Aesthetic Assessment and Theories of Beauty. Essential Psychiatry for the Aesthetic Practitioner, 49–63.

Baird, E, (2009, June 20). Fibonnaci Series Tiling, with Triangles. erkdemon. http://erkdemon.blogspot.com/2009/06/fibonacci-series-tiling-with-triangles.html

Baldvinsdóttir, U. (2013). The Wind Projects. University of Borås/Swedish School of Textiles.

Benali, S. (2020). Design of Strips with Geometry Shapes and Mathematical Analysis.

Brazhnikov, P. (2021). Social Systems: Structure, Development and Application of the Fibonacci Sequence.

Chavan, A., & Suryawanshi, C. (2020). Correlation of Fibonacci Sequence and Golden Ratio With its Applications in Engineering and Science. International Journal of Engineering and Management Research.

Desai, P. (2017). Construction of fibonacci spiral and geometry in golden hexagon using golden sections.

Duan, J.-S. (2019). Shrinkage Points of Golden Rectangle, Fibonacci Spirals, and Golden Spirals. Discrete Dynamics in Nature and Society, 2019.

Hay, J. (n.d.). ART OF THE MING DYNASTY (1368-1644).

Holden, H. L. (1975). Fibonacci tiles. The Fibonacci Quarterly, 13(1), 45.

Homlong, S. (2006). The language of textiles: description and judgement on textile pattern composition. Institutionen för hushållsvetenskap (IHV).

Ilieva, J., Kazlacheva, Z., Dineva, P., Indrie, L., & Florea-Burduja, E. (2021). A study on application of the golden and Fibonacci geometry in design of fashion accessories. IOP Conference Series: Materials Science and Engineering, 1031(1), 12026.

Kazlacheva, Z., & Ilieva, J. (2016). The golden and Fibonacci geometry in fashion and textile design. Proc. of the ERA, 10, 15–64.

Kelley, L. R. (2012). Fibonacci numbers and golden ratio. Access online.

Kristensen Johnstone, T. (2017). Surface patterns, spatiality and pattern relations in textile design. Högskolan i Borås.

Kuliš, M. Š., & Hodžić, S. (2020). The Golden Ratio and the Fibonacci Sequence in Theory and Practice. RSEP CONFERENCES, 204.

Markowsky, G. (1992). Misconceptions about the golden ratio. The College Mathematics Journal, 23(1), 2–19.

Miles, J., & Beattie, V. (2011). Surface design of textiles. In Textile Design (pp. 89–104). Elsevier.

Omotehinwa, T. O., & Ramon, S. O. (2013). Fibonacci numbers and golden ratio in mathematics and science. International Journal of Computer and Information Technology, 2(4), 630–638.

Paras, M. K., Pal, R., & Ekwall, D. (2018). Systematic literature review to develop a conceptual framework for a reuse-based *clothing value chain. The International Review of Retail, Distribution and Consumer Research, 28(3), 231–258.*

Reich, D. (2012). The Fibonacci sequence, spirals and the golden mean. Department of Mathematics, Temple University.

Sherbon, M. A. (2018). Fine-Structure Constant from Golden Ratio Geometry. International Journal of Mathematics and Physical Sciences Research, 5(2), 89–100.

Shookooh, B. R., Monajati, A., & Khodabakhshi, H. (2020). Theory, Design, and Implementation of a New Family of Ultra-Wideband Metamaterial Microstrip Array Antennas Based on Fractal and Fibonacci Geometric Patterns. Journal of Electromagnetic Engineering and Science, 20(1), 53–63.

Vico-Prieto, A. F., Cagigas, A., Rosas, J. M., & Callejas-Aguilera, J. E. (2016). Experimental approach to the study of beauty: The role of golden proportion. Psicológica, 37(2), 187–207.

Watson, A. R. (2017). The golden relationships: An exploration of Fibonacci numbers and phi. Master of Arts Thesis, Duke University.

Wille, J. J. (2012). Occurrence of Fibonacci numbers in development and structure of animal forms: Phylogenetic observations and epigenetic significance.

Yacoab, M., Sha, M., & Mustaq Ahmed, M. (2019). Secured Data Aggregation Using Fibonacci Numbers and Unicode Symbols for Wsn. International Journal of Computer Engineering and Technology, 10(1).

Yin, Z. (2020). Research on Design Aesthetics and Cultural Connotation of Gold and Silver Interlocking Buckle in the Ming Dynasty. 4th International Conference on Art Studies: Science, Experience, Education (ICASSEE 2020), 166–171.