DIGITAL WALLPAPER
TILES OF PROLIFERATION AND CONTINUITY

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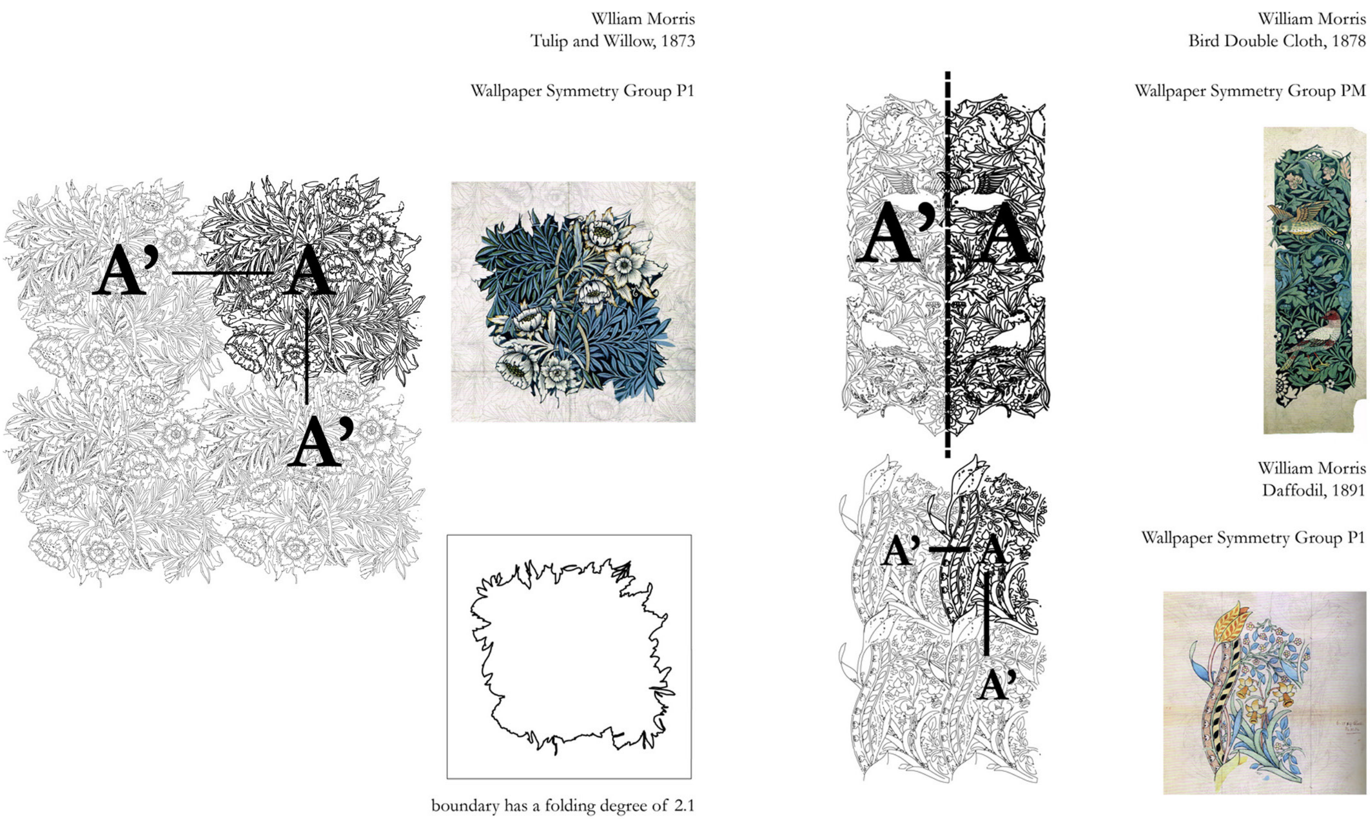


1 William Morris Wallpaper Tiling. Diagrams show methods of translation and reflection. The amorphous boundary of the tile is used to produce repetitive patterns.

ABSTRACT

This paper looks at William Morris' wallpaper designs from the Victorian era to study their intricate figural compositions and pattern transformations. As a field of graphic design, wallpapers combine organizational lattice structures and repetitive tiles that are used to decorate interior surfaces. Using growth in his designs, Morris organizes both tile boundary and its transformation to derive continuous patterns. This technique combines standardization of elements and cheapness to execute intricate, affordable solutions that could be extended to digital pattern applications.

Deriving from this historical and theoretical analysis, the paper presents a computational model that can generate digital tiles using Morris' method of blurring tile boundaries through growing figures. Various pattern elements such as leaves, flowers and veins are considered with parametric variability to create new pattern designs. The resulting continuous patterns are presented using parameters and colors extracted from some of Morris' original designs. The paper aims to reveal the digital nature of Morris' patterns and their potential extension to other design domains.

INTRODUCTION

Historically, wallpaper has been an inexpensive and simple way to dress the bare walls of a room in order to add ornament for decorative purposes. While wallpaper design has gone out of fashion in architectural practice, it has been intensively practiced by numerous historic designers until modernism. During Victorian England, this art reached its prime with the introduction of mass production, while bringing more continuity, repetition, color and pattern to its designs. One of the most influential pattern makers of this era was William Morris, who was inspired by medieval patterns and Gothic, and used similar motifs in his designs. Early in his life, Morris developed a taste for naturalism and cultivated his skills to reinvent new tools, dyes and techniques to use in his work on textiles and wallpapers. On wallpaper design, Morris listed five main conditions for "what we want to clothe our walls with is 1) something that is possible to get; 2) something that is beautiful; 3) something which will not drive us either into unrest or into callousness; 4) something which reminds us of life beyond itself, and which has the impress of human imagination strong on it; and 5) something which can be done by a great many people without too much difficulty and with pleasure" (Morris 1899). While Morris' emphasis on the importance of continuous patterns and naturalistic figures in design received much appreciation during the Arts and Crafts movement, his achievements haven't received much attention in contemporary practice. As an opportunity, this paper will look at Morris' wallpapers as an expressive avenue of investigation that could help revitalize his ideas and offer alternative digital techniques in today's pattern design.

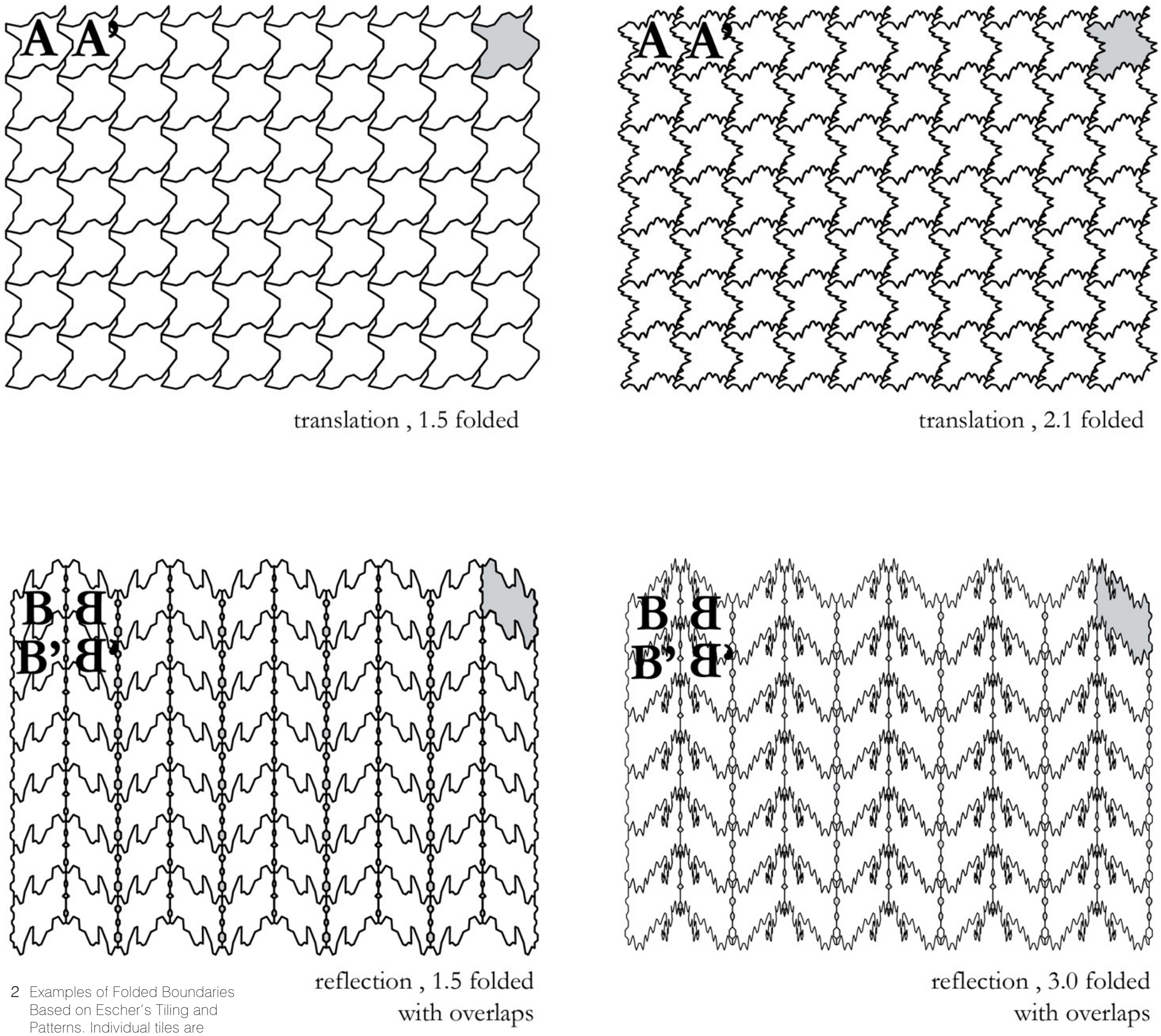
MORRIS' WALLPAPERS

Working within economic constraints of machine-based production and social dimensions of hand-made craft, Morris created numerous textile and wallpaper designs in his life that are still highly valued to this day (Parry 1996). For Morris, ornamental pattern work "must possess three qualities: beauty, imagination, and order" (Morris 1899). He defines beauty as an abundant application of naturalistic figures like twigs, leaves and flowers that all relate to the notion of nature and growth. While these continuous figures dress surfaces to make them more beautiful, they also organize the pattern by maintaining an overall directionality of growth. The second term, imagination, is related to the notion of craft and creativity of the artist that reveals his ideas and excitement through his work (Morris 1899). This principle is seen as an expression of the figures and emergent patterns that help the designer express feelings and communicate ideas to fellow craftsmen. This way the application of naturalistic figures doesn't become an "imitation", but rather liberation of the creative process that could be shared. The last term, order, is associated with the word "border" that presents an idea of limitation for the artist or craftsmen. Order helps bringing beauty and imagination together as it "invents certain beautiful and natural forms" to be placed on surfaces (Morris 1899). Since the whole scenery of an outside world could not be brought into our enclosed, living environments to appear on the walls of a room, Morris considers such borders and materiality as imposing a challenge for design. In this case, the surfaces of a room need to be covered in an efficient and repetitive fashion to represent the beauty of nature. As a result, the notion of pattern becomes a way to abstract nature and growth by employing repetitive figures within a highly ordered system.

A contemporary look at pattern design could be found in *The Sympathy of Things*, where Spuybroek considers William Morris' wallpaper designs to express their qualities of configuration through the use of non-naturalistic "abstract lines of force" (Spuybroek 2011). Although Morris uses natural figures like leaves, flowers, and twigs that could be mistranslated as "organic"; Morris' designs follow the mechanic repetition of abstract lines that offer organic iterations. Compared to geometric tiles of Owen Jones and repetitive images in Toile de Jouy's wallpapers, Morris' designs present an inherent principle of growth that organizes the border of the tiles as much as their rhythmic transformation (Spuybroek 2011). Although Morris borrows the idea of abstraction and repetition to some degree from Jones, he relies on continuous growth of curved lines to organize his patterns. The behavior of these figures articulates tile boundaries such that "the images abstract themselves enough to invent their own form of multiplication" (Spuybroek 2011). While Owen Jones follows a schematic top-down approach of tessellating surfaces and using tiles as is, Morris' diapirs dissolve the initial outlines of the underlying organization by overrunning them with growing figures (Figure 1).

TILES AND TRANSFORMATION

As a form of graphic design, wallpapers present two main constraints to achieve their technical utility. Firstly, the wallpaper needs to be composed of repetitive units (tiles) to tessellate the whole surface of the wall to be covered. Secondly, the tile repetition needs to present a form of transformation by using translation, rotation or reflection in a symmetry, which constitutes to seventeen wallpaper groups (Wely 1952). While individual tiles could be colored to reveal the underlying pattern system, adding figures over tiles helps reduce the level of abstraction and brings more continuity to patterns. There have been previous attempts to offer alternative solutions to such tessellated tile systems. Periodic, symmetrical tessellations have been considered as a way to foreground tile boundaries (Akleman et al. 2000; Serrentino 1999; Breen et al. 2007), but not as much as a system to define the



2 Examples of Folded Boundaries Based on Escher's Tiling and Patterns. Individual tiles are marked in grey color on right top of patterns..

tile as influencing the method of tessellation. Other methods explored digital algorithms such as cellular automata (Bitonti 2009) to create tiles that operate as a set of active, varying figures, but stay within a prefixed tessellated grid. In this paper, a new method is presented to systematically combine tessellation with figuring that can both inform the tile geometry and blur the effects of transformation. This method has the potential to offer an instrumental and generative framework for digital pattern design.

TILES AND IN-FILLS

In Morris' designs, the tile itself is in most cases not square, but rhomboid with irregular edges. This outline is present in hand carved wood blocks that are used in wallpaper printing in opposition to industrial methods that had emerged in late nineteenth century. When compared to the seventeen wallpaper groups (Horne 2000), Morris' wallpapers use less complex mathematical models.

In many cases, the propagation of the pattern follows the direction of growth, resulting in simple horizontal or vertical translations (p1 space group) in the case of Tulip and Willow (1873) or reflection (pm space group) in Bird Double Cloth (1878) (Figure 1). This shows that the complexity of the wallpaper group–the mathematical operation of move, mirror and rotate–can't explain the appearance of endlessness and seamlessness. It seems that the intricacy and elaboration of the meshwork of entangling lines and the resulting boundary create that effect. Morris' tiles could use simple transformations to create patterns, but the secret of his designs lies within the amorphous, irregular border outline of tiles that are twice as long as the perimeter outline of a regular geometry.

Morris' tiles also present an approach similar to Escher's isohedral tilings (Crompton 2000; Serrentino 1999), where geometrical tiles are transformed into a system of matching figures. These patterns use distorted images that are fully constrained within the border of the tiles, where they fit like puzzle pieces (Figure 2). This idea is somewhat further elaborated in Morris, where the figures follow an overall growth pattern that adjusts the tile border to accommodate a sense of continuity. In Escher's tiles, the figure and the tile become identical, whereas with Morris figures and boundary are interrelated and almost generated simultaneously. This is achieved by considering the underlying lattice only as a way to organize translation of tiles. In a way, Morris reverses the Escher effect, where the continuity is not prefixed at the level of tiles and fitting images, but rather is generated through growth that helps to organize pattern propagation and tile geometry.

STANDARDIZATION

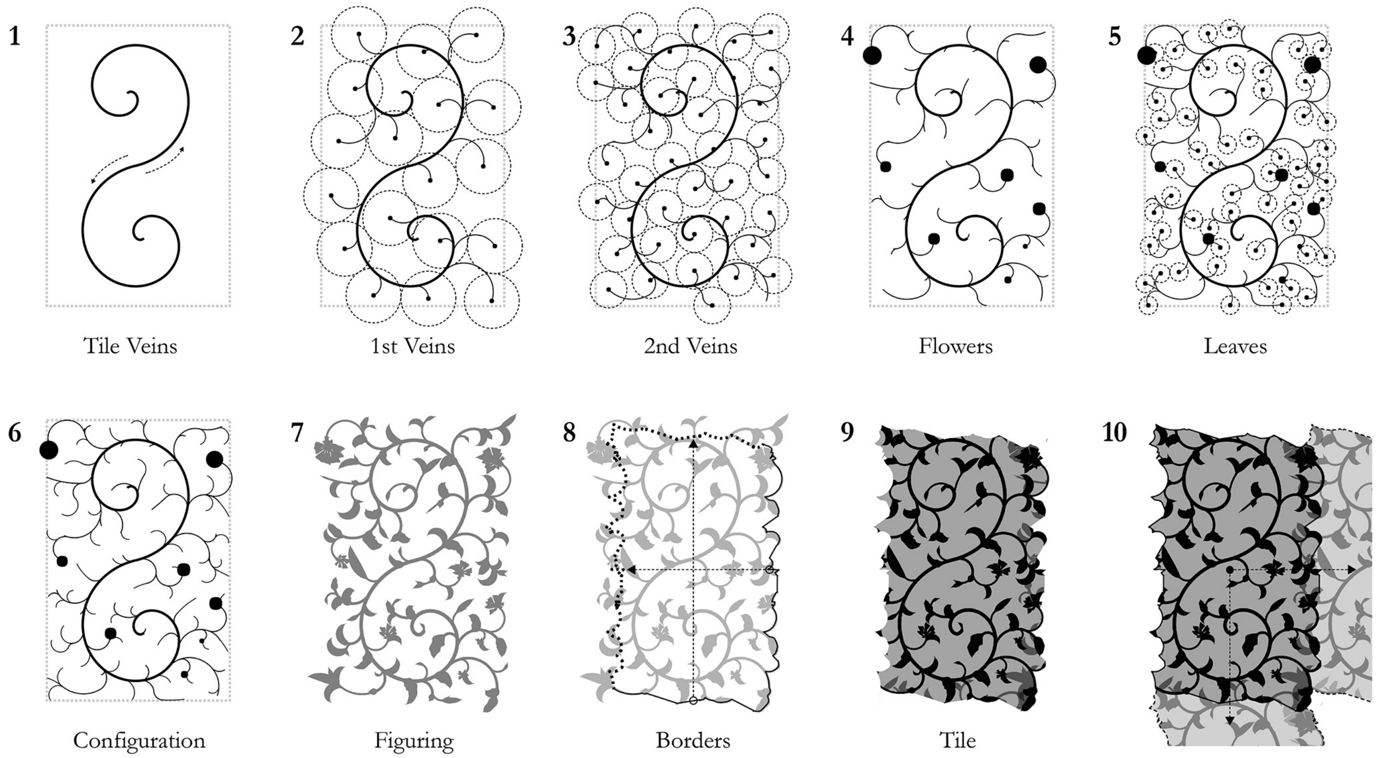
More than a century after the Arts and Crafts, the notion of craft and technology in architectural design has become fully embodied within digital tools, where architects rely on machines to design, fabricate and construct their desires. In *The Digital Turn in Architecture*, Carpo considers the recent historical developments of computerization in architecture that show how "digital technologies mass-produce variations and customize non-standards; they are anti-industrial hence post-modern" (Carpo 2013). Most of customization tools still work only on small-scale industrial products and their long term application to full-scale construction has so far failed to perform well (Carpo 2013). Although technology has been evolving at a fast pace within the design field following a certain post-modernist heritage, the industry in contrast has been slow to adapt to change. As a result, most of the production capacity in the industry still relies on mass-producible standardized elements. This presents a challenge within the design field to rethink the role of digital tools and their anticipated impact on the industry. To seek a viable alternative, the practice could benefit from a fresher look at Morris' wallpapers that successfully combine customization and mass production to achieve economical yet highly aesthetic products. Morris' designs show that standardization is less related to abstraction of figures and more to the repetition of tile. Furthermore, this form of standardization defines the wallpaper tiles as the heart of customization while their repetition could be achieved through serialized production.

CHEAPNESS

Another current struggle within the digital industry is the average cost of highly customized production methods and their scarcity. Alejandro Zaera-Polo has recently raised a theoretical concern for cheapness in design that questions the social dimensions of innovation and abundance. This concept could be better understood by studying the success of companies in other markets, such as Easy Jet, IKEA and Zara, all of which have revolutionized their industry by offering high-quality and low cost products (Zaera-Polo 2010). Among these, Easy Jet and IKEA provide "no-frills" services that both reduce the quality of their products to their bare minimal properties and offer low-cost products through optimized supply routes. On the other hand, Zara includes a certain amount "frills"–additional elements that are not part of the core product–in their design as a highly controlled extravagancy in combination with cheapness (Zaera-Polo 2010). In order to produce matching revenues against its "luxurious rivals", Zara aims to sell more goods for cheaper prices by combining a notion of mass production and limited customization. This option provides a strategic way to relate economy and aesthetics of exuberance to market share that can help redefine the social constrains of design. Such an idea was already exploited within Victorian wallpaper catalogues that included custom designs, color variations and figure combinations that could be ordered at cheap prices. This enabled the wallpapers to be mass producible and affordable to working-class people who helped expand its own market and create more revenue for designers. This strategy could be expanded to all other fields of design including architecture. Zaera-Polo concludes that "cheapness in architecture might come back as an architecture that is quite simply architecture, and not a brand", aiming to combine customization and mass production on a new level that can reinvent the current practice (Zaera-Polo 2010).

DIGITAL TILES

In order to tackle the technological gap between craft and digital production, we have revisited Morris' wallpaper designs to understand their inherent rules. We have considered an algorithm to generate digital tiles by combining recursion and space colonization methods. Following our previous analysis, this process achieves tile configuration by starting from input boundary

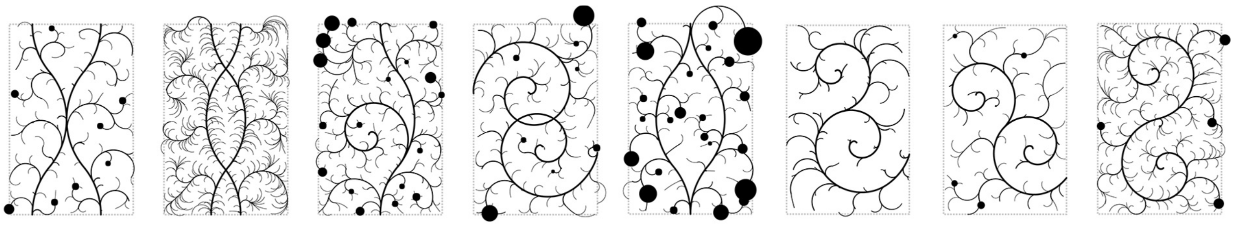


3 The Propagation Sequence of the Space-Filling Algorithm Referenced with Numbers in the Text. The algorithm starts from input curves and infills the given tile boundary space recursively by converting sampled points into bifurcating arches. The final configuration is thickened before the border is edited for patterning.

condition, primary veins (1) and parametric values to control the amount of bifurcation, flowering, thickening and coloring of figures. The algorithm is completed in two main stages. In the first stage, we use Phyton module in *Rhinoceros* that places two-dimensional curves inside a given tile shape by recursively infilling the given boundary (Figure 3). Potentially, any concave or convex tile shape could be used for the algorithm, but to exemplify the process only orthogonal convex tiles are considered for this paper.

The infilling process uses point clouds generated by a version of dart-throwing algorithm that samples points using density parameters (Mitchell 1987). After the points are placed, they are connected to their proximal veins by placing an arc using the closest point on the curve, this curve's deviation and the sampled point (2, 3, 5). Depending on the amounts of layers for figures and density, this method is called multiple times, in each step in-filling the remaining gaps of the boundary. The algorithm generates veins in proportion to the number of sampled points, while flowers are added by analyzing the curvature of the veins. If the veins deviate above a certain threshold, a circle marking the flower position is added (4). The density parameter for flowers controls the size and rate of flower placement. Using different input curves and parameter values for veins and flowers generates different tile configurations (Figure 4).

In the second phase, the configuration curves (6) are converted into thickened figures in *Grasshopper*. While the veins are visualized through offsetting only, the leaves and flowers are further articulated using parametric tools. The leaves are generated by controlling various parameters such as leaf blade thickness, vein amounts and boundary contours (Figure 5). Similarly, the flowers could be articulated by controlling the number, distribution and complexity of the petals (Figure 6).

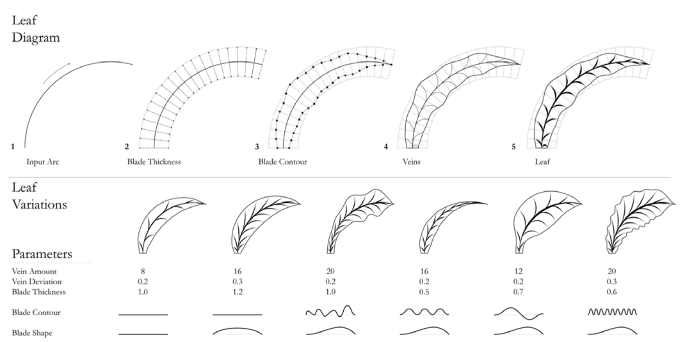


1st Layer	3.0	4.0	4.0	3.0	3.0	2.0	4.0	3.6
2nd Layer	2.0	3.0	1.5	2.0	2.0	2.0	2.5	2.5
3rd Layer	1.0	0.5	0.7	0.0	1.0	1.0	0.0	0.6
2nd Layer Flowers	0.0	0.0	1.0	1.0	1.0	0.0	0.5	0.6
3rd Layer Flowers	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0

4 Tile Variations Generated by Using the Same Boundary but Different Input Curves and Density Parameters for Tendril Layers and Flowers. The geometry of the input figure and parameters control the density of the pattern and overall distribution of elements.

Before final figures are extracted, color is added to test the visual balance of the overall pattern and distribution of figures. At this stage, parametric adjustments could be made to thicken or alter elements, before the tile configuration is extracted. To complete the procedure, each layer is first vertically placed on top of the previous layer to create the overall depth effect of the wallpaper. This is achieved by maintaining a hierarchy of figures in the order of: flowers, leaves, veins and background. The final layered model is converted into a texture map by rendering a top view image of the overall configuration (7).

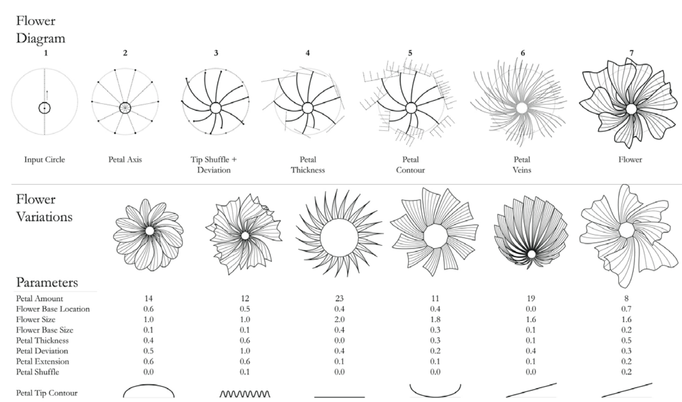
In order to create an Escher effect for patterning, the final image is further processed to extract the edge contours and resolve overlapping geometries. Firstly, the overlapping edges are defined and then copied to the opposite sides of the tile (8). Using the border contours the overlapping figures are split and relocated under final figure layer in the opposite side of the tile (9). This way pattern continuity could be maintained while blurring the edge of the tiles and resolving overlaps (10).



5 Parametric Leaf Generation Using an Input Arc Curve. The input curve is offset on both sides and then subdivided into number of veins. These vein lengths are manipulated by using two graphs (blade contour and shape) that define the final form of the leaf.

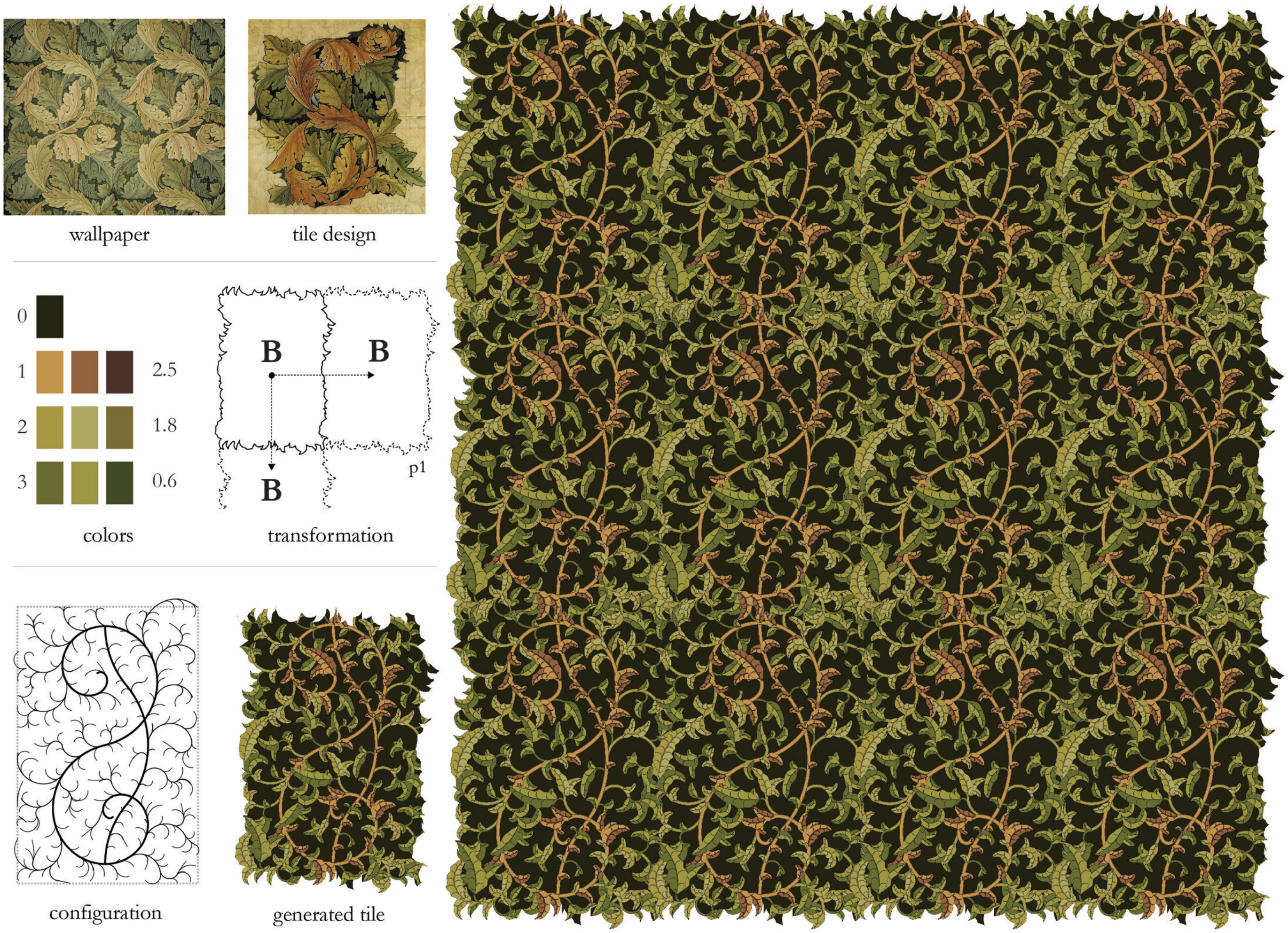
DIGITAL PATTERNS

In order to test the parametric variability and expressive dimensions of the algorithm, we have generated three digital wallpaper samples by analyzing Morris patterns. These patterns are based on Acanthus (1875), Pimpernel (1876) and Tulip and Willow (1873) designs, all of which use different tile types, colors, configurations and parameters. Morris' sketches for each pattern show how these patterns are generated by carefully articulating the figures and tile borders. In addition, these patterns express different densities, overlapping layers and amounts of flowers.



6 Parametric Flower Generation Using an Input Circle. The input circle divided into number of petals that are then connected to the base polygon. The petal geometry is controlled by using various parameters for size, thicknesses, vein lengths, angles and directions. A graph is used to articulate the tip contour of petals.

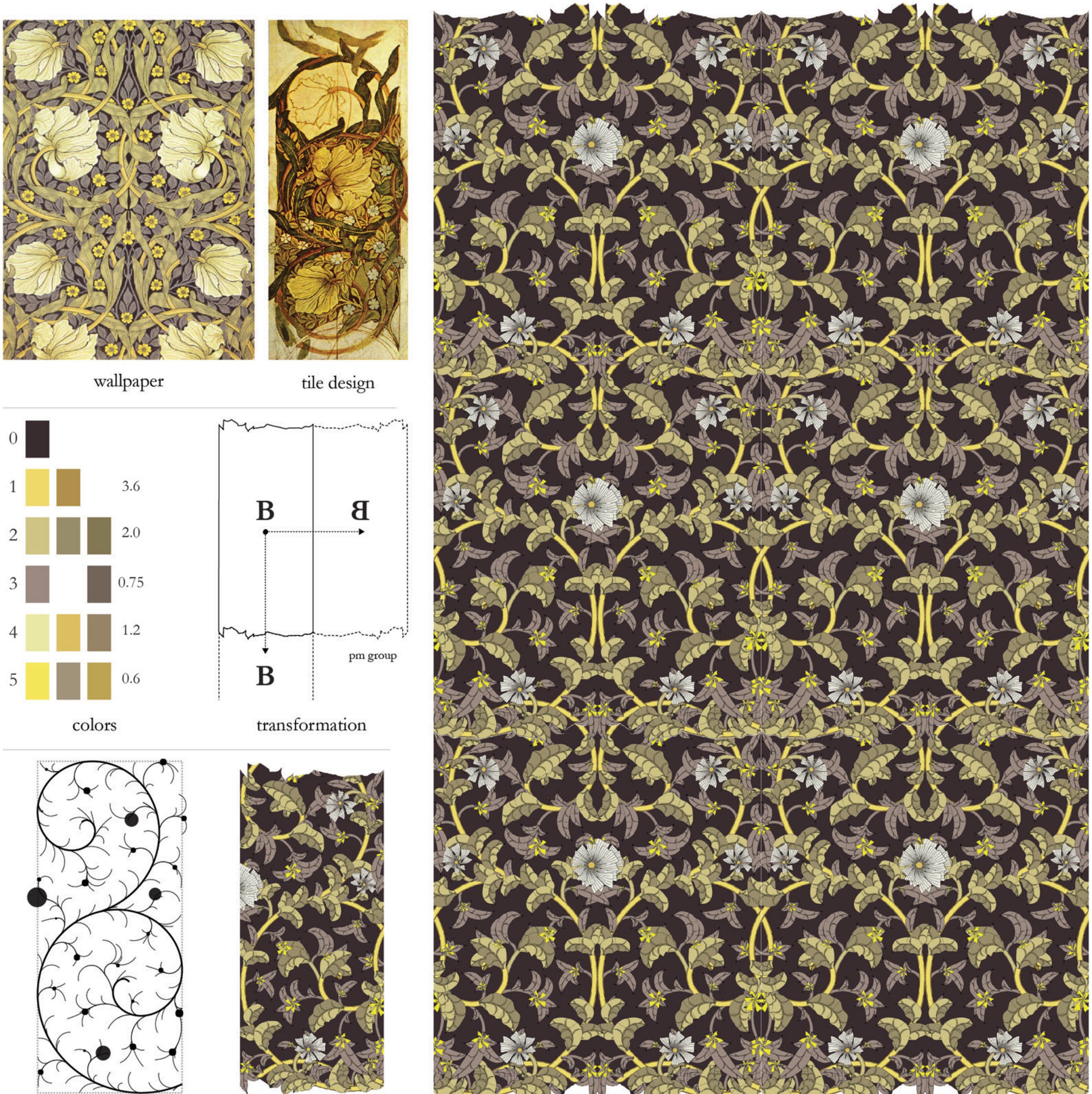
For the first layer of figures, Morris either uses spiraling twigs or vertical veins that meander through the tile (1). While these figures organize the overall structural distribution and continuity of the



7 Pattern matrix (4x3) Study Based on Acanthus Wallpaper (1875).[1]

pattern, he also considers an orthogonal tile boundary as a guide for pattern transformation (Parry 1983). Once this boundary is filled with figures, the contour is adjusted to create an Escher effect to blur the transitions (9). As a result, the orthogonal tile becomes a translational principle rather than an overall tessellation, since it is organically altered in the final pattern (10).

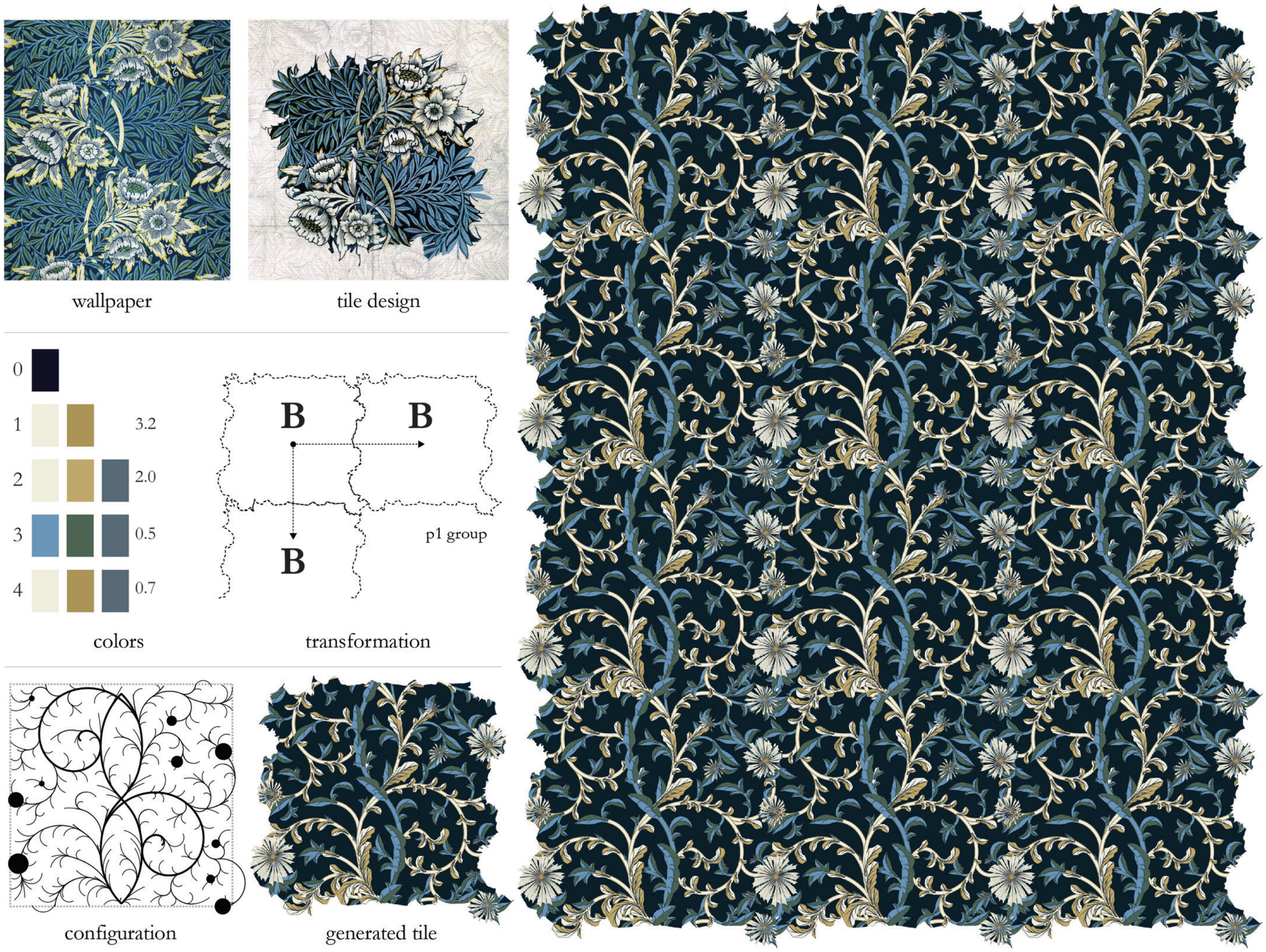
Our analysis and generated patterns show that Morris' wallpaper designs present a notion of growth and variation that can be understood through parameters and algorithms. For instance, Acanthus doesn't produce any flowers, while the tile is generated using three layers of veins and leaves that infill a rectangular boundary. Similarly, the Tulip and Willow wallpaper utilizes a square tile, while placing large-scale flowers that provide complexity. On the other hand, the Pimpernel design uses mirror symmetry to propagate the vertical and straight-edged rectangle tile. This pattern is generated using three layers for leaves and two layers for flowering with low-density parameters (Figures 7–9). Although the table shows only three types of patterns, endless configurations and color variations could be achieved by adjusting the parameters of our wallpaper generator.



8 Pattern matrix (4x3) Study Based on Pimpernel Wallpaper (1876).[1]

DISCUSSION

From a practical standpoint, wallpaper designs offer an alternative avenue of investigation that focuses on modular and customizable units that could be extended in various surface applications. For instance, the generated patterns could be tested as façade panels in different material mediums to test fabrication and construction constraints. Rather than limiting this interlocking relationship of tiles to printed media, such tiles could be assembled as building components that can offer structural stability, continuity, pattern and color to ornamental surfaces.



9 Pattern matrix (3x4) Study Based on Tulip and Willow Wallpaper (1873).[1]

The presented algorithm articulates wallpaper tiles by recursively infilling tile boundaries with abstract figures. One of the main problems with this implementation is the definition of the tile border that still relies on the user to make choices on the way that figures overlap. Another technical approach could be considered that can discretize the tile space as a cellular field, where simulation-based growth and simultaneous collision detection would take place. This can offer a viable alternative to generate precise tile boundaries that can adjust their borders automatically during growth process. In comparison, our solution offers a fast and satisfactory alternative that distributes figures in a hierarchical and layered composition.

CONCLUSION

In this paper, we have considered a digital methodology to study Morris' wallpapers to develop an algorithmic process that could generate new wallpaper designs. This investigation was presented using parametric tools that not only control tile customization, but also reveal the digital nature of Morris' designs (Spuybroek 2011). Compared to parametric surface treatments that allow isomorphic variability of tiles, digital wallpapers place the parametric variability of figures within individual tiles, while the field isomorphism is traded for cheapness. This produces continuous fields through repetition, while the effect of growth and overlapping figures blur the borders of tiles (Figures 7–9). The applied method shows potential to be extended into architectural design, where the approach could be tested through manufactured prototypes with different materiality and color constraints. As a result, amorphous boundary conditions could be further explored to evaluate the technological, social and aesthetic properties of wallpapers.

NOTES

1. On pattern tables, the left side shows the original wallpaper design and tile (top), the colors and density parameters used for layers and tile symmetry group (middle), the generated curve configuration and final image of the digital tile (bottom). The right side shows the pattern matrix achieved by copying the tile according to the transformation. The matrix numbers are written under figures (horizontal x vertical). All colors are extracted from original Morris wallpaper designs.

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IMAGE CREDITS

Figure 1.William Morris, Tulip and Willow (1873), Bird Double Cloth (1878), Daffodil (1891)

Figure 7. William Morris, Acanthus (1875)

Figure 8. William Morris, Pimpernel (1876)

Figure 9. William Morris, Tulip and Willow (1873)

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