Emphatic Lines

Surface structuring based on Walter Crane's pattern making methods

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The paper introduces a method for structuring and ornamenting double-curved geometry, which is developed through the lens of Walter Crane. Crane's method for pattern making is based on underlying scaffolds and infill patterns for two dimensional surfaces. The presented research uses his method and applies it through digitals means to three dimensional surfaces. The scaffold is used to solve the problem of curvature: it creates flat facets. This approach is tested through a prototypical installation at the Musee d'Jurassien d'Art and d'histoire using aluminium sheet metal and water-jet cutting, but can also be transferred to other architectural applications.

Keywords: *Tendrils, Patterning, Making, Facets*

INTRODUCTION

This paper presents a new form of digital pattern making over architectural surfaces by looking at Walter Crane's notion of figures and scaffolds. In "Line and Form" Crane states that the "law governing extension of design over surface" is build upon "emphatic structural lines" (Crane, 1900). A "satisfactory pattern" has to be developed based on constructive lines that can either be integrated into the design as a motive or concealed by placing the primary pattern over those lines. The scaffold allows for variation and richness: it is not perceived as a restriction. Ornament and structure are equal and can in some cases (gothic structures and ornamentations) reach a state of full integration. W. Crane applies his approach to friezes, ceiling decorations, wallpaper - in short: to two dimensional pattern making, which is based on a rectangular or triangular grid within certain boundaries (Figure 1). The presented approach applies a similar approach to both - the scaffold and the pattern - as an application for structuring a three dimensional surface.

The discussed research approach has been studied through a prototype, which was exhibited at the Art Museum of Moutier. The paper discusses the computational approach towards combining three-dimensional scaffolds and applying tendril patterns onto a three-dimensional surface. By developing Crane's technique as a parametric and recursive infilling algorithm, the paper aims to bridge between organizational tiles and logarithmic figuring as a way to achieve continuous patterns on tectonic surfaces.

PATTERN MAKING

In wallpaper designs, patterns are primarily organized by laying out a repetitive lattice to subdivide surface into smaller areas that are later replaced by figures. Such an approach is evident in Walter Crane's

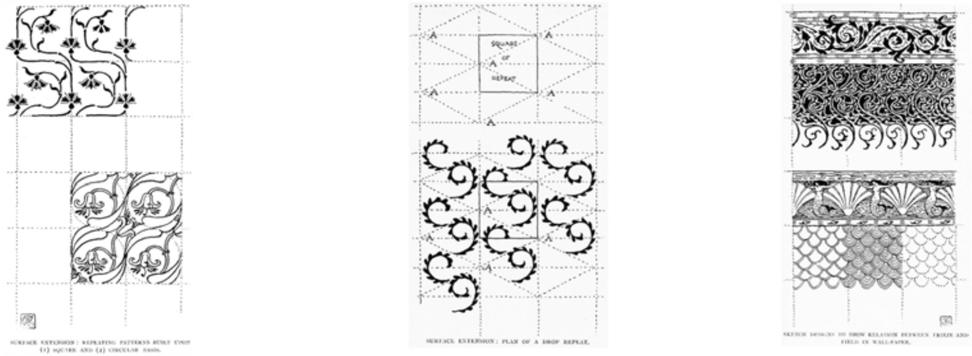

Figure 1
Left: Walter Cranes' diagrams showing designs for tendril designs based on scaffold, Right: Our algorithm that converts any polygon shape into triangles then tessellates it with veins.

designs that often utilize a grid-like tessellation to control the pattern propagation and interrelation of tiles (Figure 1). This grid is further subdivided into triangles to produce alternating repetitions of figures and interlocking relations. Although these subdivisions mainly follow orthogonal scaffolds, triangular scaffolds could enable the extension of this technique to any type of polygonal subdivisions. For instance any shape could be achieved by joining triangle patches of various sizes together. Similarly, any polygonal shape could be subdivided into triangles to convert the non-uniform shape into a number of smaller triangular tiles. As a result, Crane's rule based pattern making technique could be extended to any type of polygonal tiles, or triangulated surfaces that could be explored using digital tools.

The relationship between triangulation and figuring produces various challenges on the notion of digital pattern making. For instance, since the adjacency of tiles and the figures to be placed on top of the triangulation become more dynamic the end result can disturb the continuity and regularity of pattern. To solve this issue our paper introduces another dimension to scaffolding using an approach similar to Poisson sampling (Bridson, 2007) and recursive figure placement. Rather than placing figures directly inside triangle patches, the triangles will be used to generate uniform point clouds that define the number of figures. These points are then used to define the placement of twig figures over the triangulation using a recursive algorithm (Figure 2). As a result, the uniformity, continuity and overall distribution of pattern figures could be maintained and controlled.

The algorithm begins by subdividing any type of polygonal tile into triangular patches by joining edge curves to the center of the tile (Figure 2). These triangles are used to sample random points within the boundary with predefined or parametric density factors. Once the points are acquired the figures are placed starting from the midpoints of the edge curves of the tile using a recursive algorithm. Each figure is placed using two end points and a starting deviation to define an arc. If this arc is above a certain curvature threshold, then the arc is extended logarithmically to be turned into a twig figure. For subsequent points this operation is repeated, until all the points inside the tile have been connected to the figures. For the selection of the points the closest point with nominal deviation trajectory is chosen that maintains the overall aesthetic of the pattern while colonizing the tile space with figures.

There are various advantages of using triangulations to define this form of recursive figure placement. Firstly triangles define a plane in both two and three dimensions, since its corner points remain flat in any configuration. This enables the algorithm to be easily extended for tiles in three dimensions. Secondly, the overall triangle subdivision prevents con-

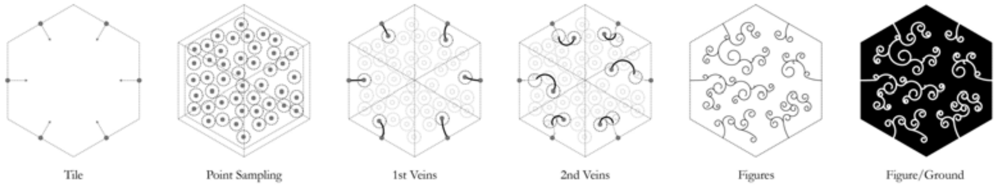

Figure 2
Stages of the vein distribution script.

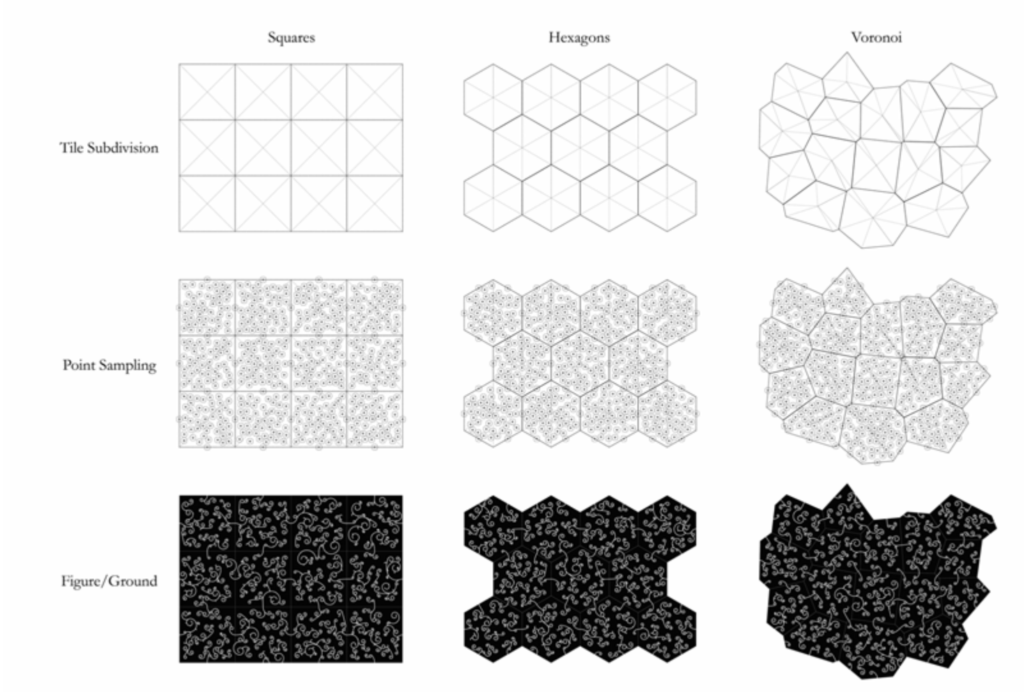

Figure 3
Testing the script on different tessellations. While the effect of the orthogonal grid in rectangle tiles (left) remain visible in the end pattern, in hexagonal (center) and voronoi (right) tessellations the tile edges become harder to notice.

struction of accidental intersections among figures that might disturb the overall pattern. Thirdly, this technique is applicable to any type of polygonal tessellations. Since any polygon shape could be subdivided into triangle patches the algorithm could be directly applied to orthogonal, triangular, hexagonal or Voronoi tessellations (Figure 3). Finally, the algorithm begins figure placement from the midpoint of tile boundary lines to connect shared edges of tiles. This approach maintains the overall continuity and curvature of figures. The resulting continuity and configuration of the pattern tends to blur the polygonal edges by overrunning boundaries with figures.

In this algorithm the point sampling is achieved by using a uniform radius to distribute point clouds inside triangle subdivisions. However, the point sam-

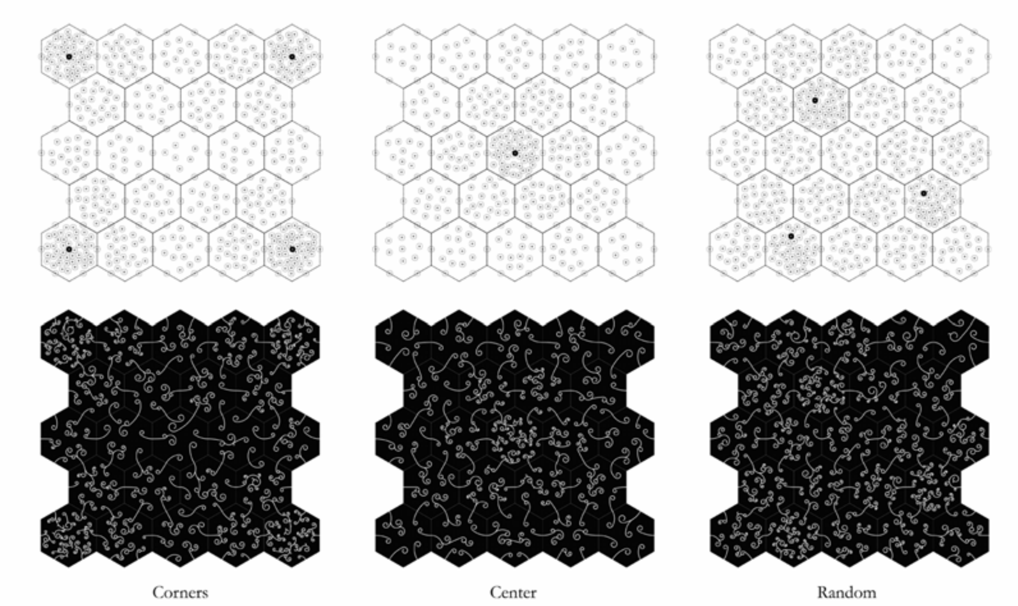

Figure 4
Parametric application of the script using different point attractor placements over the tile space

pling prior to figuring also enables using different parameters to control the density and distribution of pattern. For instance, by using multiple point attractors it is possible to create gradual variations of point density radii for different tiles. While the whole algorithm progresses in the same fashion, each tiles gets different amounts of bifurcation and tendrilling due to their distance to attractors that change the radius of point sampling (Figure 4). While the attractors could be positioned in any location over the tiles to control the density of points, the continuity of the pattern is still maintained with S-figures on boundaries that occur in low density areas.

DYNAMIC SCAFFOLDING

To test the dynamic relationship between the bifurcating figures and scaffolding tessellations we further expanded our implementation to work on three dimensional tiles. Our initial idea was to use the generated lines as patterns that will be cut out of flat metal sheets to create a figure-ground relationship. We started testing various triangle based mesh surfaces to apply our twig distribution algorithm. Although the patterns could be generated this way, the produced triangles cause various problems. Firstly, the amount of cutting out of the triangle pieces causes the final pieces to bend and lose their initial structural rigidity. Secondly, using triangle pieces results in a lot of fabricated pieces and joints to be managed to construct a three dimensional surface. Because of all these issues we decided to convert our mesh surfaces into planar facetted panels by traversing through surface information using surface normals to define flat polygons (Baerlecken et.al 2013). This approach recognizes the curvature of the surface and converts it into open edged planar tiles rather than reducing the complexity and approximating fully-connected flat pieces (Cohen-Steiner et.al. 2004). This way the continuity and curvature of the input surfaces are maintained while reducing the amount of pieces to be fabricated.

Although any surface could be converted into flat polygonal tiles, the discontinuity of edge joints between separate pieces produces a structural problem that needs to be solved in the fabrication process. While the curvature stays continuous among the tiles, the edges of the tiles appear neither collinear nor parallel to facilitate joints. To solve this issue we have defined an arbitrary centroid within the overall form that is used to extrude flanges from tile edges. This way each tile is connected to the adjacent tiles using single fasteners on flange holes (Figure 5). The flange holes are defined at an optimal distance away from the input mesh surface.

After the flat Voronoi tessellations are acquired in a three dimensional model, the vein distribution algorithm is run over planar pieces by defining a construction plane at the center of each tile. This way the same two dimensional approach could be applied to three dimensional flat tiles. Once the figures are placed over the geometry, they are grouped with each tile, later to be used as cutting patterns out of metal sheets.

PROTOTYPING AND FABRICATION

The design of the prototype was highly influenced by the digital process of preparing the digital file for fabrication as well as by the constraints of the fabrication process. The structure was planned to be fabricated through water-jet cutting of 1 mm thick aluminium sheeting. The first series of mock-ups tested the approach as surface prototypes to check the joint connections and water jet tolerances for cutting out the pattern. Prior to the fabrication process a script was written, which numbered each part and added flanges to each module. Since the scaffolding does not maintain edge connectivity, the flanges and the placement of holes become essential to determine the physical placement of each module: not all parts are lining up, but all holes need to match to avoid bending and deformation of the structure.

The design went through multiple iterations to fine-tune the number of parts with the visual appearance of the prototype. A conflict between design and economics of fabrication had to be resolved: the design was enriched by more parts and more tendrils, whereas the fabrication would save time and material (the aggregate material of the water-jet) by the use of bigger parts and less patterned elements. Figure 7 shows 3 variations ranging from 2000 facets to 500. Also, the initial intention was to further articulate the vein curves as leaves, but this produced more cutting time that couldn't be achieved within the time frame of the project. Instead the vein patterns were chosen to be cut directly out of the metal sheets to save fabrication time, while keeping the abstract aesthetics of the vein figures. Vein figures were scripted as open Nurbs curves and not as closed curves. The advantages here were that instead of four curves per tendrils, only one curve had to be cut, as well as that the programming of water-jet was much quicker and less predicated to errors of switch-

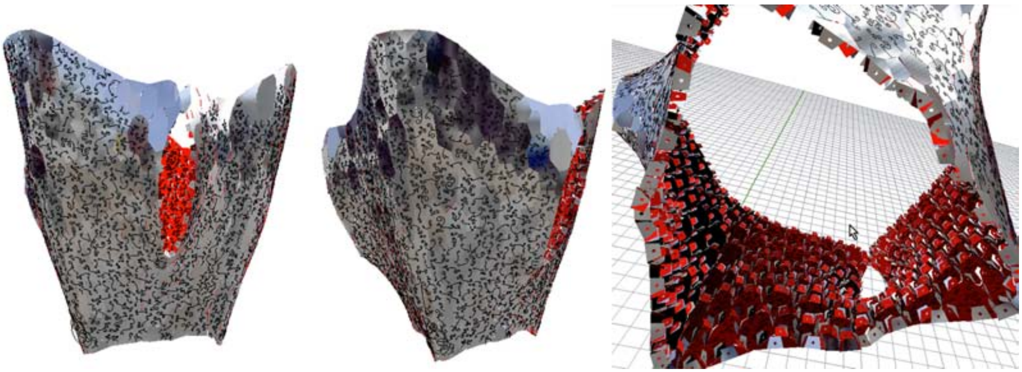

Figure 5
An early test model shown from different angles. On the right: the folded flanges on tile edges are used to construct the whole installation.

Figure 6
diagram shows different options for faceting with 1011 parts (left), 2034 parts (middle) and 550 Parts (right)

Figure 7
fabrication test with individual part (left) and different assemblies (middle and right).

Figure 8
geometric scaffold for planar surfaces (left), digital scaffolding and patterning (middle), prototype (right)

ing between interior and exterior cuts, since it was always a cut on the center of the line.

Each massing iteration was developed using the method of mesh relaxation: the underlying mesh geometry went through a tensile structure simulation with a certain number of fixed mesh points. The fixed points were in most cases placed on the perimeter of the geometry under the assumption that they perform as anchor points to the ceiling. Holes were created as part of the flat mesh tessellation, before the relaxation process was applied. The mesh relaxation was based on the Grasshopper plugin Kangaroo in some cases in combination with mesh typology modeller to create a more interesting base mesh. In order to achieve a visual interesting, non-uniform faceting pattern the meshes needed to show transformation: uneven distribution of points with fields of different densities was aesthetically desirable.

FINAL DESIGN

The final model contains less than 500 parts and the ornamentation of the tendrils was limited to certain areas. Using multiple point attractors the tendrils only grow in a certain proximity to the attractor and are eliminated in other areas. Again, this allows saving time within the fabrication process, but also enriches the complexity of the artefact.

The final design was a part of an exhibition held at the former villa Becher, which was built at the turn of the twentieth century. The musee Jurassien d'art et d'histoire is characterized through its ornamentations, painted ceilings, wooden panelling and stucco works. Those characteristic structures would have been almost destroyed during the restoration in 1995, if the department of building protection of the city Bern had not intervened.

In reference to the history of the building we designed an installation, which shows an interpretation of one of the existing baroque ceiling motives. The room, even though located in the old building, is one of the few rooms without such pre-existing ornaments. The stereometric stucco cast is transferred into a tectonic form of polygonal metal elements, which form a suspended structure through aggregation of planar facets. Relief becomes space, the single-sided surface is doubled into interior and exterior, solidness becomes thinness. A Semperian Stoffwechsel, a change of matter, takes place, where one material is informed by the properties of another. Tendrils, which are cut out of the individual facets, grow within the artefact as well as within the surrounding space through shadows that are cast through the openings (figure 8).

CONCLUSION

In this paper we presented a way to generate patterns over 3-dimensional meshes borrowing some of the historical ideas of scaffolding and figure placement. By looking at Crane's notion of pattern making the paper questions how a digital Arts and Crafts could be created that define a dynamic relation of pattern and form. This notion considers computation and fabrication as main determinants for the implementation of certain rules that lead the production of ornamental architectural surfaces.

Future research could focus on building skin for large scale buildings. The use of facets allows to incorporate a concept of cheapness into the design as an active design principle and not as a post-rationalization process. The application to other materials such as pre-cast concrete panels, laminated glass panels and double-layered rainscreen facades has to be studied to understand each materials potential and constraints. For example the use of pre-cast panels with highly expensive moulds seems to postulate an approach with more repetition and intelligent use of tiles - an idea that is very present in Crane -, whereas the use of laminated glass would enable more pattern variation.

Another very promising application could be found in interiors. Especially interiors of hospitality could be enriched by highly ornamented tilings. This application would be a literal return to Crane as those surfaces tend to be flat and two dimensional and require intelligent methods of tiling and studies of corners, boundaries and edges.

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