3D Webs: Interweaving Rhythm, Geometry and Crochet

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Abstract

This paper explores the intersection of rhythm, mathematics and crochet, presenting a novel methodology for designing and constructing large-scale 3D netted compositions using chain stitch techniques. This approach to crochet pattern design aims to present a time-efficient, versatile and scalable method of generating large-scale art installations, informed by interdisciplinary considerations of rhythmic structure. Through an iterative, practice-based research process, this work highlights the possibilities for using mathematical logic to render complex, large-scale crochet art installations.

Introduction

"What do rhythms look like?" This was the primary question in my PhD exegesis [10], exploring how rhythmic patterns can inform netted, chain stitch designs. This paper distils some of the key findings from this practice-based research, highlighting the mathematical logic of the approach and discussing implications for the creation of large-scale public art works.

Crochet is a dynamic and evolving art form that bridges traditional craft, contemporary activism, and mathematical exploration. While various crafts such as knitting, weaving, and macramé have been employed to create intricate structures, the large-scale, netted, biomorphic forms discussed in this paper are uniquely suited to crochet. The flexibility and stretchiness of the chain stitch, in particular, allow for the creation of expansive, adaptable installations that can be tensioned and shaped to fit unconventional spaces.

Rooted in a history of subversive feminist art, crochet has also emerged as a powerful tool for visualizing complex mathematical concepts, with significant contributions from artists and academics alike. Daina Taimina's work on hyperbolic crochet models [12] has been foundational, demonstrating the potential of crochet to model complex mathematical forms. The Wertheim sisters of the *Institute For Figuring* have further expanded this field with their international *Crochet Coral Reef Project* [13], which combines art, mathematics, and environmental activism. Shiying Dong's *Crocheted Topological Surfaces* [2] have also made notable contributions, exploring the intersection of crochet and topology. These works have established crochet as a valuable medium for visualizing and understanding mathematical concepts, and have extended the potential of crochet in new contexts. For example, Taimina's research on the use of crochet in educational settings has shown its effectiveness in teaching complex mathematical concepts [3]. Additionally, the crochet coral reef project illustrates how these concepts may be leveraged in participatory fine art contexts to illustrate biomorphic forms found in nature [14]. However, crochet's inherent synergy with mathematics and rhythm presents opportunities for deeper exploration and appreciation of the medium.

While crochet has been explored in mathematical and artistic contexts, its potential for generating large-scale tensile structures using 3D Platonic solids as scaffolds remains underdeveloped. This research establishes a methodology for integrating rhythmic and geometric frameworks with crochet-based design to create scalable, netted installations. Further extending on the foundational work of Taimina, the Wertheim sisters, and Dong, this research contributes to the field of crochet mathematics through a novel approach to 3D pattern generation informed by interdisciplinary approaches and Platonic solid structures.

By integrating concepts from geometry, music, and psychology, this study offers a novel approach to crochet pattern design, and illustrates implications for tensile, biomorphic form creation. The following sections will outline the methodological approach, as informed by rhythmic structure, highlight applications in large-scale art installation contexts and discuss the future development of the body of work.

Methodology: Conceptual Foundations

This section outlines the conceptual foundations to the methodology used to generate netted crochet structures, informed by geometric principles and rhythmic patterns. The chain stitch, as a foundational element, will be briefly discussed. The following subsections will then consider how rhythmic logic can be used to generate Euclidean and non-Euclidean patterns.

Chain Stitch as a Foundation

All designs featured in this practice-based research use the chain stitch. This is a versatile technique used in various applications, from creating intricate lace patterns and decorative borders to forming the foundation for more complex crochet projects. The chain stitch is used in this study as it is the most efficient stitch in terms of resources required, as opposed to stitches such as the single crochet or double crochet stitches, which require additional physical actions and therefore more time and materials to render. Much like drumming, where each hit of the drum equates to a count in the measure, each loop in the chain stitch can be equated to a single unit of measurement. In this body of work, we see these chain stitches counted out as sequential number progressions to generate visual patterns. An example illustration of a chain of crochet stitches is shown in Figure 1, including the corresponding count for the first ten stitches of the chain. The following sections will discuss how this approach is used to generate 2D tessellating patterns (Euclidean), and the generation of circular phyllotaxis designs (non-Euclidean).

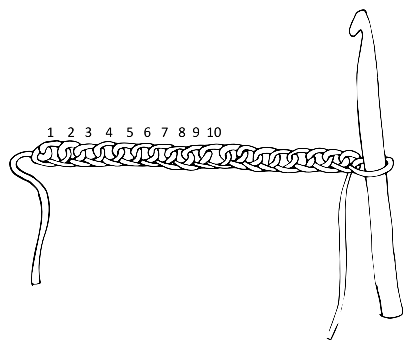


Figure 1: *Counting the chain stitch. Diagram by Louisa Magrics, 2022.*

Rhythmic Divisibility

Rhythm, as experienced in drumming, is deeply rooted in patterns and counting. This concept extends naturally to crochet, where counting chain stitches becomes a rhythmic act. Inspired by divisive rhythms, I have explored how patterns in time translate into patterns in space, using crochet to visualize these structures.

Drawing from this logic, the starting circle chain may be divided into regular intervals, with accents placed at specific points. A division of the circumference by the number of sides of the shape creates a proxy of the shape, further defined when the corner loops come under stress. This approach, unifying rhythmic patterns, geometry and crochet pattern generation, is seen in Figure 2. Here we see 12 hits of the hi-hat divided to create different kinds of rhythmic patterns, paired with their corresponding shapes and examples of resulting 2D netted structures. Colour is used to illustrate the construction method, starting in the middle with the lightest colour and working outwards from the centre. Each accent in the pattern corresponds to corners in the shape and indicates a joining slip stitch in the next rotation. Further investigation may allow for more complex tiling of shapes, provided the sequences of numbers used are appropriate for the design context.

Designs always start from the centre and are created in an anticlockwise motion with a continuous flow. This process mirrors the embodied experience of drumming, where a drummer enters a flow state - a heightened state of focus, immersion, and effortless movement - through repetitive, precise rhythmic execution. Flow Theory, introduced by psychologist Mihaly Csikszentmihalyi [1], describes this optimal experience, in which time seems to dissolve, and actions feel seamless. In both drumming and crochet, this state of flow enhances efficiency and creative expression, enabling a seamless and rhythmic progression of movement and form. By using repeated counting sequences in these designs, I have consciously curated a workflow which maximises the effects of flow psychology, allowing for an optimised construction process. As each piece needs to be physically rendered, this is a critical consideration and has allowed for a productive practice-based research process, generating the extensive body of work created to date.

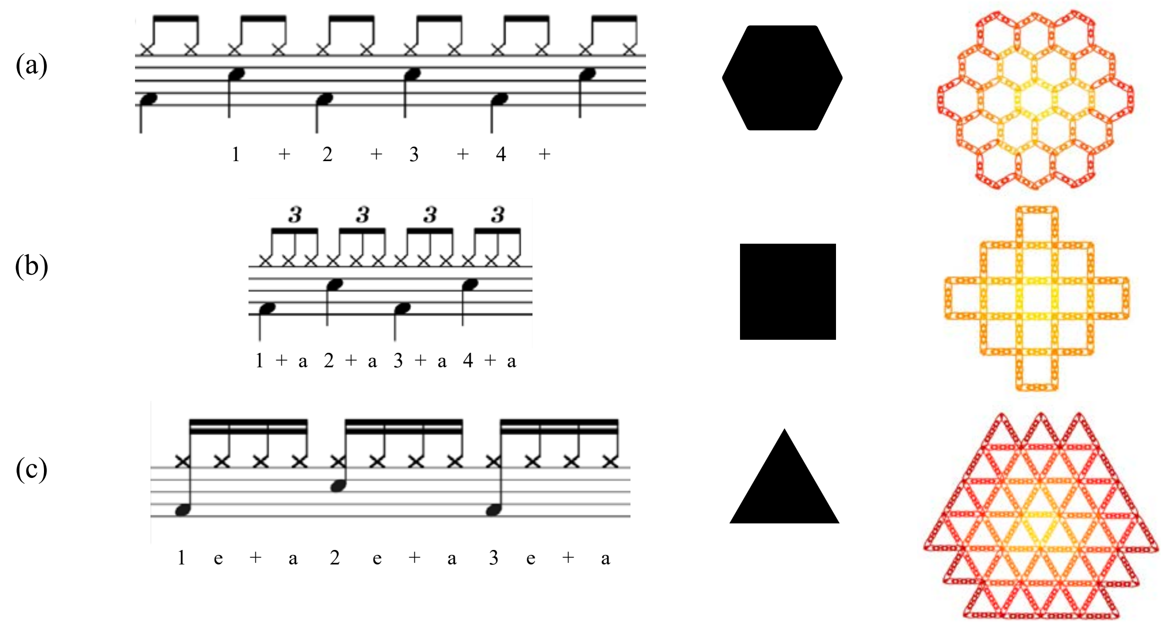


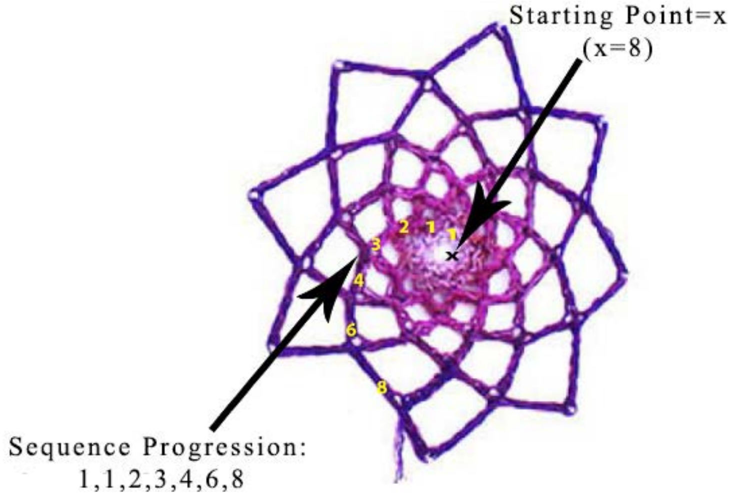
Figure 2: *Examples of Divisive rhythms with 12 hi-hat beats, including corresponding counting methods. The number of divisions is equal to the number of sides in a shape, (a) generates a hexagon, (b) generates a square, and (c) generates a triangle. An illustration showing the use of this logic in the context of 2D pattern generation is included.[9]*

Phyllotaxis Designs: Additive & Polyrhythmic Approach

This section will consider a non-Euclidean approach to pattern generation. The creation of netted phyllotaxis designs informed by additive and polyrhythmic structures is outlined. The following sections will consider how principles of rhythmic divisibility may be applied to phyllotaxis patterns to generate 3D structures.

While rhythmic divisibility occurs when there is a repetition of a standard measure, another way to consider rhythm is additive, where sequences of number are progressively added to create bars of varying length. Another novel consideration is polyrhythms, where different divisions of the bar are overlayed. These alternative approaches to rhythmic structure have inspired a non-Euclidean style of pattern generation, where numbers are overlayed and increase with each round. This has led to what I refer to as the "phyllotaxis design" –this term refers to the arrangement of leaves or petals around a central axis and is often seen in nature, for example in succulents, pine cones and sunflowers, as shown in Figure 3a. Figure 3b provides a visual example of a crocheted phyllotaxis pattern. This pattern features polyrhythmic elements, for example in the overlaying of a count of 3 over 2, and additive rhythm elements, seen in the addition of stitches with each progressive cycle. While in this example the number of nodes in the circumference remains constant, additive rhythm elements are also seen in later designs with addition of nodes to the circumference. Similar to the approach shown in Figure 2, the number of nodes along the circumference must be divisible by the number of sides of the shape to effectively utilise the geometric properties of Platonic solids in designing 3D crochet compositions.

(a)



(b)

Figure 3: *(a) Example of phyllotaxis pattern found in the disc floret of a sunflower. [11] (b) Example of crocheted phyllotaxis pattern featuring 8 nodes. Numbers increase with each round to generate a radial spiral pattern. The work is generated in an anti-clockwise motion, with a continuous flow. Changes to the rate of expansion will affect the curvature of the structure, when tensioned outwards from the centre.*

In my initial studies, these circular forms were added together randomly to create large-scale "free form" installations [5][8]. Due to the non-uniform structure, I found these works were difficult to install. Through iterative refinement, the divisive rhythm approach allowed me to consider how the phyllotaxis pattern could be used more effectively in the context of 3D compositions. Figure 4 provides a visual example of how divisive rhythm logic is applied to create proxies of 2D shapes. If we consider a phyllotaxis pattern with 12 nodes, this can be used in the context of a triangle (4 nodes per side), a square (3 nodes per side), or hexagon (2 nodes per side), as illustrated in Figure 4. This lead to consideration of Platonic solids as scaffolds for generating biomorphic 3D designs, and is discussed further in the Applications section.

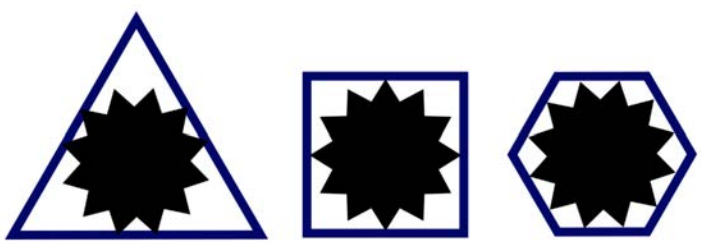


Figure 4: *Illustration showing how a phyllotaxis pattern with 12 nodes may reference different geometric shapes. A triangle will have sides with 4 nodes, a square will have sides with 3 nodes, and a hexagon will have sides with 2 nodes. Note, in this context, corners are omitted – leading to the generation of biomorphic forms.*

Applications: 3D Forms & Tensile Structures

This section builds on the methodology presented above by considering the use of phyllotaxis designs in the context of 3D Platonic solid scaffolds. The iterative development of the design methodology is discussed through applications in various contexts, including wearable artworks and large-scale public art installations. Here, construction of the designs is informed by Platonic solid structures. Essentially, values are relative and proportional, allowing for optimised forms with overall symmetry, cohesion and spatial harmony. Colour and material are considered as additional variables which help support overall visual cohesion.

Head Sized Study Series

To iterate this conceptual approach through practice-based research, I initially started creating Platonic solid scaffolds at a standard 'head size,' as shown in Figure 5. Working at this scale allowed for a spatially efficient approach during the design ideation and iteration phase, while the work was able to double in use as performable objects.[6] The values used to generate these forms are relative and proportional, following the structure of their corresponding 3D Platonic shapes. These studies provided a proof of concept for larger designs, and informed my approach to structuring 3D crochet compositions at scale.

(a) (b) (c) (d)

Figure 5: *3D Design Studies, based on Platonic solids, part of the Head Sized Study Series, 2015: (a) Square Pyramid, (b) Octahedron, (c) Cuboctahedron, (d) Decahedron.*

Parabola

My first large-scale installation working with the logic of Platonic solid geometry was based on the structure of a tetrahedron, requiring four panels to generate the structure, as shown in Figure 6. [7] Here a large phyllotaxis design with a standard circumference is repeated 4 times, for each face of the tetrahedron shape. The circumference is divided by 3, and joined along each of the edges to generate the form. While the design was successful in creating a harmonious structure, appropriate for large-scale public art contexts, the use of materiality resulted in a physically heavy form – limiting its capacity to respond to a wide range of site-specific contexts. This was due to multiple yarns being used at once to render the form, which were changed incrementally to embed colour gradients in the work.

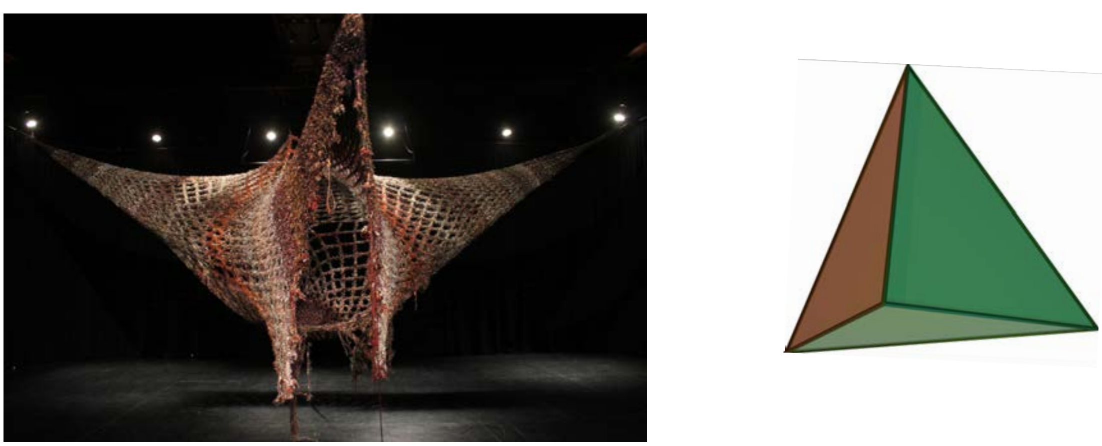


Figure 6: *Parabola, 2015, large-scale installation based on the geometry of a tetrahedron structure. Installed at the University of Newcastle, Australia. Artwork dimensions approximately 4 m x 6 m x 5 m.*

While the design works well in a gallery setting, the size, materiality and weight creates a logistical challenge in responding to environments outside of this context. As a result, rather than embedding colour through material, future iterations explored a minimalist approach by rendering the work in a single strand of white yarn or rope. This resulted in a light-weight design which aesthetically responds to a wide variety of environments, and allows for site-specific collaborations with lighting designers. This approach is illustrated in Figure 7, and discussed in more detail through the next section.

3D Webs

(a)

(b)

Figure 7: *3D Web Designs, with a starting point of one, expand through the addition of nodes to the circumference, in line with an additive rhythm methodology. The division of the circumference of each panel, or "face" of the square shape, uses a divisive rhythm approach as seen in Figure 4 and is equated to a cubic structure. (a) Acrylic Version 1, 2016. Artwork dimensions approximately 1.5 m x 1.5 m x 1.5 m, (b) Rope Version 1, 2017. Installed at the University of Newcastle, Australia. Artwork dimensions approximately 8 m x 8 m x 8 m.*

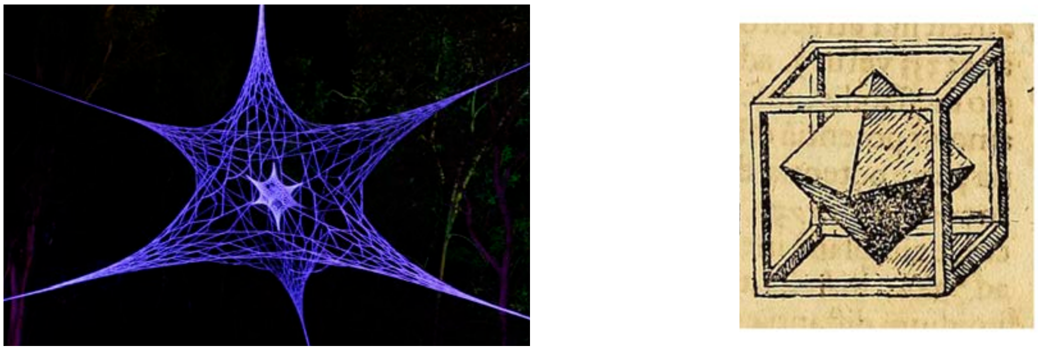
In these studies, titled "3D Webs," [4] a cubic structure is used to render the form. This essentially allows for the creation of the biggest internal space with a minimal amount of tether points, requiring only three points upwards and three points downwards to tension the form outwards. These points alternate spatially in an equilateral triangle configuration. While a tetrahedron structure requires fewer tether points, the cubic structure allows for a larger internal cavity space, creating greater impact in large-scale public art contexts. The design is also easily scaled, allowing for a time efficient construction method for large installations. Changes to the sequence progression, as discussed in the Phyllotaxis section, will result in different curvature in the tether points. This can be seen in Figure 7a which features a progression of smaller increments, while (b) features a progression which expands at a faster rate. With limited variables to take into account in installing the work, I have found these structures very easy to install in a variety of site-responsive settings, including forests, galleries and outdoor urban environments. The following sections will discuss how this design can be further extended upon, to create more complex 3D netted structures.

Dual Solid Structures

The next step in the development of this conceptual framework was the consideration of dual solid geometry. Dual solid geometry refers to a pair of polyhedra where the vertices (corners) of one correspond to the faces of the other and vice versa. This logic provides a conceptual scaffold for further developing these designs and creating more complex large-scale, netted structures.

Using the logic of dual solid geometry and the 3D web design as a starting point, I began to consider how a second form could be mounted inside of the larger structure. In this case, the 3D web uses a cubic structure and features 6 phyllotaxis designs for each face of the Platonic solid. As seen in Figure 4, the divisive rhythm approach to applying geometric logic results in a loss of vertices in the shape, creating a void in the overall structure where edges of the shape converge.

The corresponding dual of the cube is an octahedron, with 8 faces that correspond to the 8 vertices of the cube. Each of the individual phyllotaxis pieces start with a piece of thread in the centre, and therefore a point is created at the centre of each panel, or "face" of the polyhedric structure. To mount an internal structure, these points are attached to the "corner" voids of the outer structure to create a proxy of a dual solid shape, as seen in Figure 8a. This results in a visual inversion of the form. For example, while the internal dual of cube is an octahedron, it aesthetically looks like a cube, as seen in Figure 8a and Figure 9b.



(a) (b)

Figure 8: *(a) Hyperweb at Mushroom Valley, 2017. Artwork dimensions approximately 6 m x 7 m x 7 m. (b) Johannes Kepler, Diagram of an octahedron and cube as a dual solid form, 1619.*

Triple Web and Embedding Colour

The number of layers embedded in the structure is only limited to size of the outer form, the weight of the material, and the artist's ability to physically construct and assemble the work. Theoretically, this design approach could be repeated many times over, with additional layers. The latest development in this series of works has been the creation of my first "triple web" design study, created in 2024, featuring 2 internal layers embedded within the outer structure. Scale is critically important in this context, with smaller hook sizes required to render and mount the interior structures. Colour has become a consideration and feature of the work when including additional layers. The sequencing and selection of colour embeds meaning and leads to subjective interpretations of the subject-matter. *Embedded, 2024*, as shown in Figure 10, provides an example of a yellow, pink and black colour treatment. Yellow has been used for the central form to reference a source of light or brightness. In the context of the black colour used on the outer structure, the piece referred to the notion of finding a spark of light amongst darkness.

(a) (b)

Figure 9: *Example of triple-web structure, featuring a cubic structure for the central yellow form, an octahedron structure for the pink layer, and a cubic structure for the outer black layer. (a) Embedded, 2024 (b) Embedded, 2024 (Detail). Installed at Straitjacket Art Space, Newcastle, 2024.*

Summary and Conclusions

This research has explored the mathematical concepts such as repetition, symmetry, division, and geometry through the medium of crochet. By integrating principles from geometry, music, and psychology, this study has developed a novel methodology for generating netted 2D and 3D tensile structures. The use of chain stitch designs, inspired by divisive rhythms and phyllotaxis patterns, has demonstrated the potential for creating complex, scalable, and visually striking forms.

Key findings include the development of a detailed methodology for generating netted crochet structures, informed by rhythmic patterns and geometric principals. The work showcases an interdisciplinary approach, demonstrating the integration of concepts from drumming sequences, flow theory, and geometry to inform crochet pattern design. Practical applications are illustrated through the creation of large-scale public art installations, showcasing the versatility and scalability of this approach. The significance of this research lies in its potential to inspire a range of material outcomes and offer new perspectives on creative practice. By demonstrating how crochet can be used to model mathematical concepts, this study provides a framework for artistic and design applications.

Future research directions include further development of large-scale, netted crochet designs for use in public art contexts, sustainable and eco-friendly art (through use of continuous pattern design and "no-waste" approaches) and in the development of ergonomic crochet patterns. Overall, this research has shown that the intersection of rhythm, geometry, and crochet offers a rich and versatile framework for creative practice. The methodologies and applications developed in this study have the potential to impact the fields of art and mathematics, inspiring future innovations and interdisciplinary collaborations.

Acknowledgements

I am grateful to my mother for teaching me to crochet when I was a child, and both of my parents for their continued encouragement and support. I would also like to acknowledge support provided by the University of Newcastle, and would like to thank my mentors, including Braddon Snape and Faye Neilson. Thanks also to Aleksej Lavrinec for his guidance, feedback and support.

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