Representing and Creating 3D Bobbin Lace

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Abstract. This article presents a new method for designing 3D bobbin lace patterns that addresses the lack of specifications and difficulties faced by novice users when using conventional pictorial symbol patterns. The methodology presented demonstrates the feasibility and potential for preserving traditional techniques, exploring new possibilities and advancing the field.

Keywords: Bobbin Lace, Lacemaking Gestures, Textile Design, 3D Meshes.

1 Introduction

Bobbin lace is a textile technique developed thanks to the perfection of trimmings, which allows the creation of decorative elements such as braids or tassels. In 2008, Mick Fouriscot added this technique to the French Cultural Heritage List (Fouriscot, 2008). The process involves the interweaving of several threads in space to create an openwork fabric (Souriau & Souriau, 1990). There are different varieties, families, and types of lace specific to each region. Standardised protocols are used to produce high quality bobbin lace. This requires a uniform colour, the absence of deformations and a regular pattern without stains or impurities. For almost three centuries, lace making was widespread in Europe (Risselin-Steenebrugen, 1980). Each region developed its own styles and patterns. In the 19th century, lace became a full-fledged industry with factories and workshops employing thousands of lacemakers. The rural department of Haute-Loire in France is an example of an organisation that has developed a genuine economic system based on the production of handmade and then mechanised lace. According to Trincal's research (Trincal, 1999), the number of lacemakers in the department had exceeded 100,000 in 1860. It is worth nothing that throughout history lace was considered as a symbol of social status and was often used to decorate clothing and household textiles such as lampshades, doilies and curtains. Handmade lace is valued primarily for its decorative qualities, while other functional aspects are rarely considered or appreciated. Its popularity has fluctuated over time in response to changing trends and fashions. Nevertheless, bobbin lace techniques have diversified and evolved over the centuries. This development has made it possible to produce ever finer and more complex lace patterns. However, the basic creative process and possible uses of lace have remained unchanged since the publication of Giovanni Battista's collection of ornamental lace patterns (Battista & Sessa, 1557).

Incorporating modern technology into traditional lacemaking techniques has the potential to significantly reduce the tedious and time-consuming design and production stages. It also enables the creation of intricate and precise designs that are difficult to achieve by hand. Recent studies have developed and modelled the automatic generation of a lace pattern to improve and streamline the production process using mathematical modelling techniques. For example Veronika Irvine (Irvine & Ruskey, 2014) proposed a tessellation-based approach that characterises repeated elements on a pattern. The pattern can then be simulated using parametric mathematical modelling based on graph theory. This simulation allows the creation of a software tool called Tesselace (Irvine, 2019) which automatically generates pair and thread diagrams for 2D pattern representation. This software led to the development of the collaborative tool Groundforge (Pol & Tempels, 2020), which brings together lacemakers from around the world to create a tool suitable for designing new lace patterns.

Several recent studies have shown that the use of digital technologies such as Computer-Aided Design (CAD), 3D printing and 3D scanning can be combined with lace in innovative projects, as demonstrated by the work of Lisa Marks (Marks, 2019). Similarly, these digital tools can also be combined with industrial lace as demonstrated in Ma(T)isse breast reconstruction project (Ma(T)isse-project, 2018). These studies suggest the possibility of experimenting with the creation of 2D laces designed using parametric methods. Our objective is to take this concept further by proposing the design and manufacture of a 3D pattern that serves as a foundation for the lacemaker to produce their work. The lace is thus made directly on a three-dimensional pattern, requiring a rethinking of the traditional techniques and gestures involved in its production. This article explores the potential for designing and producing a three-dimensional lace using innovative technology to extend its range of applications. The proposed method involves the use of LaceApp software to create a 3D pattern. The chosen lace design is inspired by a special type of bobbin lace called “Torchon” (Brulet & Brulet, 1995). This type was very popular in Europe and dates back to early forms of lacemaking (Baum & Boyeldieu, 2018). The “Torchon” has several advantages such as its strength thanks to its simple geometric patterns made of continuous threads. In addition, this study explores the potential utility of using water-soluble materials in the production of lace patterns.

2 Methods

2.1 Traditional Bobbin Lace Technique

From a practical perspective, lacemaking relies on a limited number of precise and controlled movements. The complexity of making a lace model lies in the multitude of points that require a high degree of technical knowledge. The process follows a tradition that has been passed down orally through generations and consists of several procedural steps.

Creation of the pattern called "carton"

The lacemaking process traditionally begins with the creation of the "carton", also known as the "pattern". This pattern guides the lacemaker through the manufacturing process (Baum & Boyeldieu, 2018). The lace pattern is first traced onto tracing paper and checked for consistency (Fig.1). In this way, various parameters such as the number of bobbins, the type of stitches, the thickness of the thread and the scale of the pattern can be determined. Once these parameters are determined, the sketches are converted into a technical drawing and transferred to a piece of cardboard using Chinese ink. The cardboard is then perforated where the pins will be positioned using a wooden tool with a metal mandrel. Finally, the technical drawing is protected with a transparent adhesive.

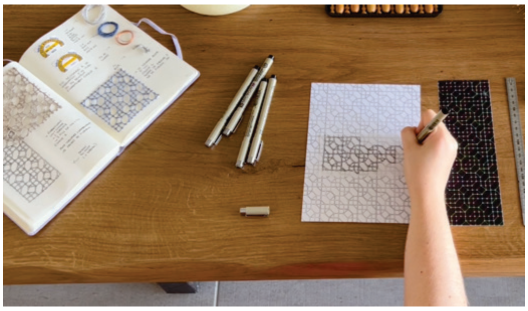


Fig. 1. The process of creating a visual representation of a pattern on tracing paper.

Preparation of the tools

In addition to the "carton", tools are needed to make the lace. Bobbins are the main feature of this type of lace. These are small wooden tools about 8 to 10 centimetres long. They are used to hold the different threads. The lacemaker manipulates them to create the lace. The next step after creating the carton is to wind the bobbins with the appropriate thread. Each set of bobbins is wound with a single thread and arranged in pairs (Fig. 2). The technical drawing and the paired bobbins are then placed on the bobbin lace cushion called the "carreau". This cushion forms a stable base for the subsequent production of bobbin lace. The shape and size of the cushion may vary depending on the country or type of lace work.

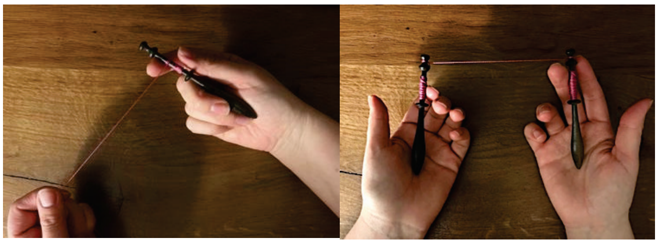
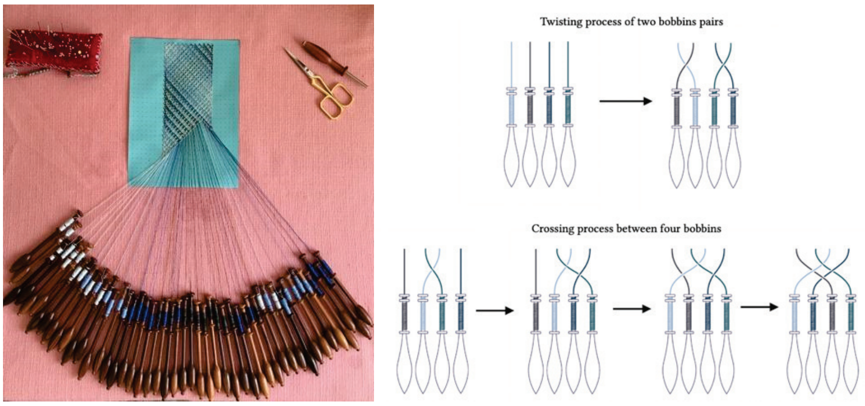


Fig. 2. Winding the yarn on the bobbin and assembling the pair of bobbins, from left to right.

Fabrication of the bobbin lace

Once these steps have been completed, lace production begins. Lace patterns are made by interweaving several threads together with two main movements. These two movements are described in the textile encyclopaedia as twists and crossings (Baum & Boyeldieu, 2018). The realisation of these movements involves the use of a cushion, bobbins and threads as described above (Fouriscot et al., 1982). Twists are made between two yarns of the same pair, while crossings can involve several pairs of bobbins (Fig. 3). The basic bobbin lace crossing consists of four threads and is illustrated as follow: 2 over 3, 4 over 3, 2 over 1, 2 over 3 (Centre d'enseignement de la dentelle au fuseau, 2008). Fifty bobbins are necessary to create a "Torchon" lace with a width of about ten centimetres. The exact number of bobbins required may vary depending on the type of stitch employed. The movement of the bobbins creates intertwined lace patterns (Fig. 3). The crossings and twists are secured with pins placed at a slight angle to prevent the work from unravelling. Once the bobbin lace is finished, the threads can be crocheted, knotted or simply interlaced. Crocheting is a process in which the path of some or all the threads is interrupted. After crocheting, the threads are cut and the pins are removed. The "carton" can be thrown away or stored for later use.



(a) (b)

Fig. 3. (a) A representation of traditional bobbin lace technique. (b) The twisting and crossing steps of bobbins.

2.2 Modelling the 3D Meshes to Bobbin Lace

The first step in the process of creating a 3D "carton" is to develop a CAD tool inspired by the field of knitting (Narayanan et al., 2018). The proposed visual programming method starts with a 3D object whose mesh is modelled by a geometric Yarn model. Once the 3D modelling and printing of the object is complete, a technical drawing is produced and transferred to an industrial knitting machine. This machine produces the knitted fabric to pre-defined formal specifications. Once the knitting process is complete, the resulting piece is placed on a mould. This three-dimensional way of manufacturing is called Seamless knitting, as the final product is produced in one seamless step (Browaeys, 2019).

The LaceApp was developed based on this visual programming methodology. LaceApp aims to convert 3D meshes into a 3D model with lace texture. A skeletonisation technique using Reeb graphs is used to segment the mesh (Edelsbrunner & Harer, 2010). The Tesselace model is then propagated from a starting point of the 3D shape along the width of the mesh (Fig. 4). This process is implemented using Python 3.8 to generate graphs of lace patterns with their corresponding textures. These graphs are developed using the Networkx library and are then converted to lace textures using Python's native library for image processing, PIL. A function has been added to track the path of the lace threads segment by segment. It makes it possible to check the consistency of the technical model with the help of GIF. The LaceApp offers various customisation options, such as changing the aesthetics of the pattern, selecting the lace points, changing the colour and scale of the threads and more. Visualising patterns is made easier by automating the steps to design lace on 3D meshes, such as tori or spheres.

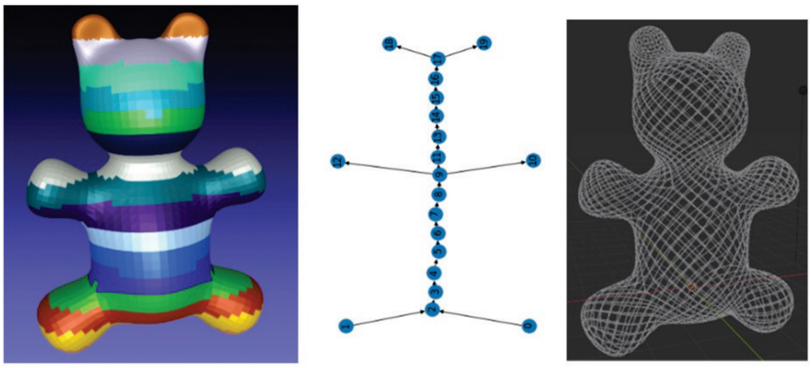


Fig. 4. 3D shape, skeletonisation and 3D Torchon lace representation.

2.3 3D Lacemaking

This study presents a new approach to lacemaking that integrates 3D modelling and additive manufacturing techniques. The process starts with the design and modelling of the "carton" in 3D using an algorithm. The resulting design is then manufactured using additive manufacturing. This creates a three-dimensional "carton" that accurately reflects the predetermined design, complete with holes for the pins to be placed. This 3D-printed "carton" serves as the basis for the manual bobbin lacemaking process. Instead of the traditional cushion, the lacemaker uses the 3D "carton" as a support to start the production of the lace. The pairs of bobbins used in this process are made of flax fibres twisted with metal threads and then attached to the 3D "carton" with pins. Flax fibre is chosen for this manufacturing process because of its technical suitability. This fibre becomes more resistant when submerged in water, has absorbent qualities and is rotresistant. (Jacquet, 2020). The use of flax fibres also has a historical significance linked to the traditions of bobbin lace. Indeed, this fibre was appreciated for its qualities and was widely cultivated in Europe.

3 Results

3.1 3D Meshed Model

The use of the LaceApp software application allows the modelling of the thread paths directly on the 3D shape and the precise determination of the pin placement. Figure 5 shows a numerical thread path on the selected shape with different colours indicating the different pin positions. The tool allows the pattern to be scaled to fit the shape of the object and the threads to be coloured for easy visualisation during the sampling process. Experiments have shown that 92% of the holes are accurate. This accuracy makes the process of lacemaking on the three-dimensional object efficient.

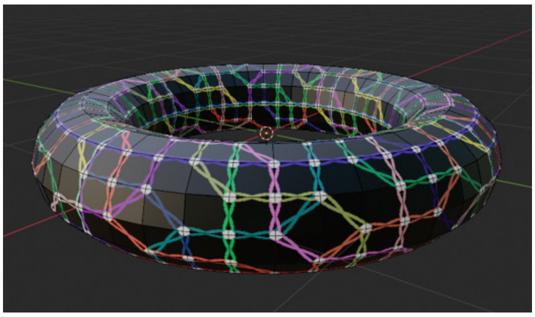


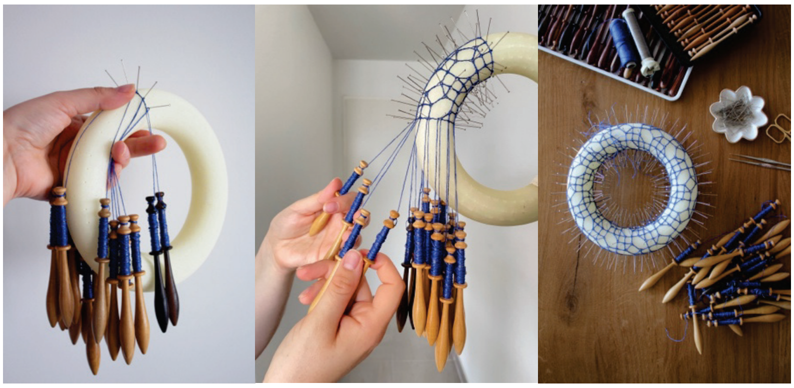
Fig. 5. A numerical representation of the three-dimensional lace pattern.

3.2 Three-dimensional Printed Pattern Card

The method for producing the three-dimensional "carton" involves the use of a water-soluble PVA material and layer-by-layer printing with a 3D printer. The resulting 3D "carton" has dimensions of 129 mm in length and 31 mm in thickness. By using water-soluble materials, the intricate 3D "carton" can be dissolved without the need for traditional pattern making or sewing techniques. In this way, the lace can be adapted directly to the contours of the object instead of being limited to a flat shape. The 3D "carton" is provided with perforations that serve as a visual guide for the placement of the lace pins during production. The perforations also allow the threads to be interlaced according to the intended design.

3.3 Fabricating Bobbin Lace on 3D Shapes: A Feasibility Test

This technique allows the production of dynamic and intricate lace patterns that go beyond the limits of traditional two-dimensional lacemaking methods. Figure 6 shows how the lace is made on a three-dimensional printed support, which serves as the basis for the manual lace work. A major change in this type of production is the way the bobbins are held and how the "carton" is manipulated in three-dimensional space. This production from 3D modelling confirms that the pins are correctly placed with over 92% accuracy. There are no errors in the model, the different distances and the different shapes are similar.



(a) (b) (c)

Fig. 6. (a) Installation of the bobbins on the 3D "carton". (b) Lace fabricated on the 3D printed support, tubular work. (c) Completion of lace production, threads cut.

The pins are removed after the bobbin lace has been made on the 3D printed support. Then, the piece is immersed in a 40°C water bath for 2.5 hours to dissolve the 3D "carton". Once the "carton" has completely dissolved, the lace is placed on a wire rack to dry. The plastic material dissolves, leaving only the lace structure, which remains intact and does not deform (Fig. 7). The material does not shrink and the dimensions between the different intersections correspond to those measured before the dissolution of the "carton".

(a) (b) (c)

Fig. 7. (a) Torus at the pre-dissolution stage. (b) Torus during immersion. (c) The final product.

4 Conclusions

The research aims to demonstrate the effectiveness of incorporating digital tools into the production process of handmade bobbin lace. The result is the production of three-dimensional lace while maintaining traditional techniques and gestures. The study confirms that the use of digital tools facilitates the design of the technical drawing, the pattern and thus the production of the lace. The ability to visualise the arrangement of the threads in a three-dimensional space through direct virtual simulation on the object saves time in the design process. Drawing the lace digitally with software such as Lace-App creates a precise and coherent pattern that optimises the consumption of threads needed to produce the desired item. Immersing a flax piece in water to dissolve the "carton" did not cause any deformation, deterioration of the colour, or affect the appearance of the object. In conclusion, the production of a piece of 3D bobbin lace using the proposed method confirms the feasibility of this process and demonstrates the potential of digital technologies to improve lace craftsmanship. The use of a 3D pattern enables the creation of complex and dynamic designs that go beyond the limits of traditional 2D lacemaking. This study highlights new possibilities for the future of lacemaking by demonstrating how conventional methods and digital technologies can work together to produce innovative designs while preserving craftsmanship.

Acknowledgements.

This work has been supported by the "France Relance" or "Relaunch France" which the aim is to boost the competitiveness of the French economy and create a fertile environment for innovation.

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Received: March 14, 2023
Reviewed: April 15, 2023
Finally Accepted: May 05, 2023