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LITHOPHANE PRODUCTION BY TRADITIONAL AND 3D PRINTING METHOD- A REVIEW PAPER

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ABSTRACT

Lithophanes are three-dimensional artworks that display a detailed image when backlit. Traditional methods of producing lithophanes involve carving an image into a thin sheet of material, such as porcelain or resin. However, with the rise of 3D printing technology, lithophanes can now be produced with greater speed and precision. This review paper provides an overview of both traditional and 3D printing methods for lithophane production. It covers the advantages andlimitations of each method, as well as the materials and techniques used. The paper also explores the impact of various parameters on the quality of lithophanes produced by 3D printing. While traditional lithophane production requires a high level of skill and time, 3D printing technology offers greater flexibility in design and ease of production. However, the choice of materials and printing parameters are critical factors in achieving high-quality lithophanes. Furthermore, the paper discusses the potential applications of lithophanes in fields such as art, education, and medicine.

Keywords: 3 D printing, Lithophane, FDM

I. INTRODUCTION

Lithophanes are three-dimensional images that are created by carving or molding a translucent material, such as porcelain or wax. The image is created by varying the thickness of the material so that when it is illuminated from behind, the image appears with varying degrees of light and shadow. The origins of lithophanes date back to the late 18th century, when they were first produced in France. At the time, lithophanes were primarily used for decorative purposes and were often featured on household items such as lamps, vases, and plates. Lithophanes became especially popular during the 19th century, when advances in mass production techniques made them more affordable and accessible to the general public. Traditionally, lithophanes were produced using a labour-intensive process that involved carving or molding a translucent material by hand [1- 3]. In the modern era, however, the development of digital imaging technology and 3D printing has made it possible to produce lithophanes much more efficiently and with greater precision. Today, lithophanes continue to be used for decorative purposes, but they have also found a place in other applications,

such as medical imaging and security printing. With the development of 3D printing technology, the production of lithophanes has become even more versatile and accessible, making it easier for artists, designers, and hobbyists to create their own custom designs [3].

3D printing is a manufacturing process that involves building three-dimensional objects by depositing layers of material, typically plastic or resin, on top of each other. In lithophane production, 3D printing technology is used to create a three- dimensional model of the lithophane, which can then be printed in a translucent material to produce the final product. There are several 3D printing technologies that can be used for lithophane production, including fused deposition modeling (FDM), stereolithography (SLA), and digital light processing (DLP). FDM is the most common 3D printing technology used for lithophane production due to its low cost and accessibility. In FDM printing, the printer extrudes a thin filament of thermoplastic material, typically PLA or ABS, and deposits it layer by layer to create the lithophane model. The printer head moves back and forth, depositing the material in a precise pattern that follows the contours of the model. Once the model is complete, it can be sanded or polished to achieve a smooth finish, and then illuminated from behind to produce the final lithophane image. SLA and DLP printing are also used for lithophane production, particularly for more complex or detailed designs.

In these technologies, a liquid resin is cured by a laser or light source to create the lithophane model. The resulting models can have finer details and smoother surfaces than those produced by FDM printing. Overall, 3D printing technology has revolutionized the production of lithophanes, making it faster, more efficient, and more accessible than traditional production methods. With the ability to create custom designs and produce high-quality models, 3D printing has opened up new possibilities for artists, designers, and hobbyists looking to create unique and personalized lithophanes. The significance of 3D printed lithophanes lies in the many benefits they offer compared to traditional lithophane production methods.

Some of the key benefits include:

1) **Increased efficiency:** 3D printing allows for faster and more efficient production of lithophanes, with fewer labor- intensive steps and less waste.
2) **Greater precision and detail:** Highly elaborate and detailed designs that would be difficult or impossible to create with traditional methods can now be created thanks to 3D printing.
3) **Customization:** With 3D printing, it's easy to create custom designs for lithophanes, whether it's a personalized image or a unique shape or size.
4) **Accessibility:** The utilisation of 3D printing technology has expanded the audience for lithophanes, extending beyond artists and designers to include hobbyists and do- it-yourself enthusiasts.
5) **Versatility:** 3D printed lithophanes can be made using a wide range of materials, including plastics, resins and ceramics, allowing for a variety of aesthetic and functional applications.

II. LITERATURE REVIEW

A. Historical background on lithophanes

The history of lithophanes can be traced back to the 18th century, when they were first produced in France. The word "lithophane" comes from the Greek words "lithos" (stone) and "phanos" (light), reflecting the translucent nature of the material and the way it interacts with light. Early lithophanes were typically made by carving or molding a thin sheet of porcelain or wax to create a three-dimensional image. The image was created by varying the thickness of the material, with thinner areas allowing more light to pass through and thicker areas blocking more light. Lithophanes quickly gained popularity in the late 18th and early 19th centuries, particularly in Europe and North America. They were often featured on household items such as lamps, vases, and plates, and were also used in religious and commemorative contexts. In the 19th century, advances in mass production techniques made lithophanes more affordable and accessible to the general public. Lithophane factories were established in Europe and the United States, and lithophanes became a popular decorative item in homes and public spaces. Over time, the production of lithophanes evolved to include new materials such as plastics and resins, and new techniques such as photolithography and 3D printing. Today, lithophanes continue to be used for decorative purposes, but they have also found applications in areas such as medical imaging and security printing. Overall, the history of lithophanes reflects a rich tradition of craftsmanship and innovation, as well as a continuing interest in the interplay of light and materials in creating beautiful and meaningful images [1-3].

B. Traditional methods of lithophane production:

Traditional methods of lithophane production involve a manual process of carving or molding a translucent material to create a three-dimensional image. The process typically involves the following steps:

1) **Preparation of the material:** The translucent material, typically porcelain or wax, is prepared by being flattened and smoothed to a consistent thickness.
2) **Creation of the image:** The image to be carved or molded onto the material is transferred onto it. This can be done by hand, or by using a transfer sheet or tracing paper.

3) **Carving or molding:** The image is then carefully carved or molded into the material. This is a delicate and time- consuming process, as the thickness of the material must be varied precisely to achieve the desired effect.

4) **Firing or cooling:** Once the image has been carved or molded, the material is fired in a kiln or cooled to set the shape of the image.

5) **Finishing:** The lithophane is then finished by being sanded or polished to achieve a smooth surface, and may be painted or glazed to enhance the image.

The traditional method of lithophane production is a labor- intensive process that requires skilled artisans to create the desired effect. While this method is still used today, it is primarily used for high-end, artisanal products and is not as accessible or cost-effective as 3D printing [1].

Despite its limitations, the traditional method of lithophane production remains a valued craft and art form. Its unique blend of artistry and technical skill has inspired countless artists and designers throughout history and continues to inspire new generations today.

C. Comparison of 3D printing methods and materials for lithophanes:

There are several 3D printing methods and materials that can be used for lithophane production, each with their own strengths and weaknesses. Here are some of the main differences and considerations when comparing these methods and materials:

Fused Deposition Modeling (FDM): Due to its low cost and ease of usage, FDM is the most often used 3D printing technology for lithophanes. To generate the lithophane model, FDM printers use a filament of thermoplastic material, such as PLA or ABS, which is melted and deposited layer by layer. FDM printing is best suited for producing larger, simpler patterns with less features. Layer lines are visible in the resultant models, which can be reduced with sanding or polishing.

Stereolithography (SLA): SLA is a 3D printing technology that creates the lithophane model by curing a liquid resin with a laser. SLA printing is great for producing intricate, detailed graphics with a smooth surface quality. The generated models have no apparent layer lines, but may require UV light and washing post-processing.

Digital Light Processing (DLP): DLP is similar to SLA printing, except instead of a laser, it employs a light projector to cure the liquid resin. DLP printing is faster than SLA printing and creates higher-quality prints. The generated models have no apparent layer lines, but may require UV light and washing post-processing.

Material: The choice of material can also affect the final appearance and quality of the lithophane. Translucent materials, such as PLA or resin, are ideal for lithophanes as they allow light to pass through and create the desired effect. However, some materials may have a higher level of transparency or color tint that can impact the final image. Metallic filaments can also be used for a unique effect.

Overall, the choice of 3D printing method and material will depend on the specific design and desired outcome of the lithophane. FDM printing is cost-effective and accessible, while SLA and DLP printing offer greater detail and smoother surface finish. The choice of material can also impact the final image quality, and should be carefully considered.

D. Analysis of current research on 3d printed lithophanes:

M.Yuan et al [4], discusses the challenges and considerations involved in producing lithophanes using additive manufacturing techniques. The paper covers a range of topics, including the nature of light transmission and absorption, the development of contrast and brightness, grayscale to thickness conversion, and the impact of layering on quantized grayscale development. The author also discuss the importance of lithophane orientation with respect to the light source, noting that this can have a significant impact on the appearance of the image. In addition, they suggest strategies for optimizing lithophane quality, such as choosing the right material, adjusting printing parameters, using post-processing techniques and carefully managing lighting conditions.

Hadley brooks et al[5], discusses method of creating personalized lamps using image processing and additive manufacturing. The process involves the customer or designer submitting images which are then processed to create 3D surfaces on the exterior of the lamp. The 3D surfaces act as lithophane, which are illuminated from behind using LED lights, producing a highly personalized and visually striking lamp. The paper highlights the potential of this method to revolutionize the lighting industry by allowing customers to create their own highly personalized lamps and tap into the growing demand for customized products. Overall, the paper presents an innovative and customizable process with significant potential for the lighting industry.

Mengqi Yuan et al [6], explains how optically translucent items made with additive manufacturing techniques like laser sintering and stereolithography can be made of higher quality. With a focus on polyamide 12 material, the study looked at manufacturing concerns, lithophane production standards, and the optimum translucent material and additive manufacturing technique. The scientists discovered that cyanoacrylate infiltration and polishing may reduce the surface roughness of laser-sintered parts, and that the ideal layer and plate thicknesses for laser sintering were 0.076 mm and 5 mm, respectively. The optical characteristics and functionality of components made by stereolithography and laser sintered were also contrasted in the study. The study is the first to systematically examine quality improvement concerns for LS PA optically transparent parts and offers insightful information on the additive manufacturing of optically translucent parts.

Seung-Ho Jang et al [7], discusses lithophane are typically printed with a high infill density to create a grayscale effect, which can make the printing process slow and time-consuming. The proposed technique aims to reduce the printing time by adapting the extrusion rate based on the layer complexity of the lithophane. The authors first analyze the complexity of each layer of the lithophane and categorize them into three types: simple, medium, and complex. They then propose an algorithm that adjusts the extrusion rate based on the layer type, with higher rates for simpler layers and lower rates for more complex layers. To evaluate the effectiveness of the proposed technique, the authors conducted experiments using a standard FDM 3D printer and compared the printing time and quality of lithophanes printed with and without the adaptive extrusion control technique. The results show that the proposed technique reduces the printing time by up to 30% without significantly affecting the quality of the printed lithophanes. Overall, the proposed technique presents a promising approach for reducing the printing time of lithophanes using FDM 3D printing while maintaining good print quality.

Hyeonsu Han et al [9], conducted an experiment to find the ideal parameter values for the production of lithophane, a 3D printing method that creates 3D objects from 2D images. The authors investigate parameters like vector per pixel, thickness, and breadth of the thinnest layer that significantly affect the quality of 3D objects. They also look into the relationship between the clarity of the 3D object and the production time. The authors evaluate the parameters and convert the created 3D object back to a 2D picture using Matlab. They find that there is an asymmetry between the time needed to construct the three- dimensional object and its level of clarity. Additionally, they discover that the difference between the thickness value and the width of the thinnest layer has a significant impact on the standard deviation of the reconverted 2D image, whereas the vector per pixel has no influence. The fact that the study only examined three elements related to the lithophane's surface and that the light source may not have equally lit the surface is one of its drawbacks. Additional features, like the light source, might have provided further details.

A. Singh et al [8], This study describes a method for transforming 2D digital photos into 3D STL files for additive manufacturing. The technique is written in MATLAB and uses a weighted method to convert RGB photos to grayscale images. The grayscale image that results is then turned into a 3D model that can be created using a 3D printer. The research also discusses the effects of picture brightness and layer count on final output, as well as printing time and filament length for various image formats. The algorithm shown here can handle 2D images for 3D printing and has potential uses in the fashion and jewellery industries for manufacturing personalized, sophisticated products at a cheaper cost. Finally, the paper recommends that additive printing could be used to create nature-inspired products such as earrings based on various flower models.

Another research paper by Hyeonsu Han et al [10], the researchers experimented with different parameters, including shape, thickness and resolution, to optimize the design for the tactile sensation of low vision blind individuals. The results of the study showed that the most influential parameter was shape. The researchers found that a round shape was optimal because the printing mark, which is inevitably generated during the printing process, did not greatly affect the tactile sensation for low vision blind individuals. In fact, the researchers found that the printing mark helped low vision blind individuals recognize the shape more clearly when they touched the surface. The researchers also conducted a questionnaire among visually impaired individuals to confirm their findings. The results of the questionnaire supported the conclusion that the printing mark not only did not damage the human figure itself but also improved the recognition of the shape for low vision blind individuals.

Song tingqiang et al [12], the article discusses a contradiction in generating digital models of light-transmitting reliefs, where simplified operations can lead to poor quality models, while better quality models require complicated generation methods. To address this issue, the authors propose an image enhancement method based on grayscale compression, which can improve the image quality of high-transmittance relief digital models with a simple setting. The method is tested on a unique printing material, and its effectiveness is compared to existing model generation methods. The article concludes that the proposed method has significant advantages in the final molding effect and ease of operation, effectively resolving the contradiction between low model quality and complex generation methods.

Jinlei wang et al [11], this research paper presents a method for automatically creating personalized lithophane lampshades based on a 2D target image and a 3D lampshade surface. The method involves using laplacian-based mesh deformation to flatten the surface, establishing a mapping relationship with the target image, and then using poisson-based surface reconstruction to generate the lithophane. An optimization step is then applied to adjust the coordinates of the lithophane, and users can adjust the input source and thickness of the lampshade. This paper show that the method is effective in creating lithophane lampshades with target images shown under lighting.

III.METHODOLOGY USED FOR PRODUCTION OF 3D PRINTED LITHOPHANE

The methodology used in lithophane production involves a combination of image processing, 3D modeling, and 3D printing technologies. The success of the lithophane production process depends on careful selection of images, proper image

processing, and appropriate choice of printing technology and parameters.

1) **Image Selection:** The first step is to select an appropriate image for the lithophane. Typically, images with high contrast and varying shades of gray are preferred.
2) **Image Processing:** The selected image is processed using specialized software to convert it into a grayscale image and to enhance the contrast between different parts of the image.
3) **Lithophane Generator:** A lithophane generator is used to convert the processed image into a 3D model. The generator creates a 3D model with varying thickness, where the thinnest parts of the model correspond to the brightest parts of the original image, and the thickest parts correspond to the darkest parts of the image.
4) **3D Printing:** The 3D model is then 3D printed using a suitable 3D printing technology, such as Fused Deposition Modeling (FDM), Stereolithography (SLA), or Selective Laser Sintering (SLS). The choice of printing technology and printing parameters can have a significant impact on the quality and visual appearance of the lithophane.
5) **Post-Processing:** Once the lithophane is printed, it may require some post-processing steps to improve its visual quality. This can include sanding, polishing, or painting the surface of the lithophane.

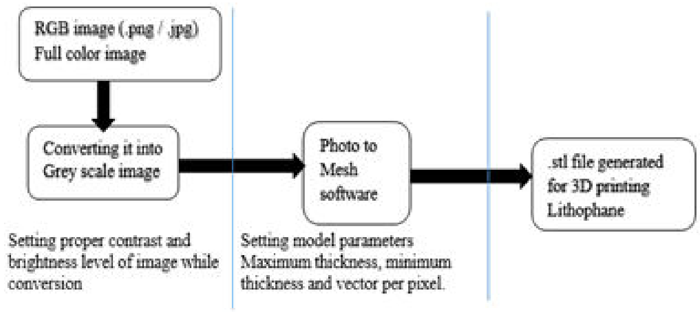

Figure 1: Steps to convert digital full color image file into

.stl file.

Converting an RGB image to a grayscale image involves calculating a weighted average of the color intensities of each pixel. The formula to convert an RGB image to grayscale is:

Gray = 0.2989 * R + 0.5870 * G + 0.1140 * B

Where R, G, and B are the red, green, and blue components of the pixel, respectively. The numbers 0.2989, 0.5870, and 0.1140 are the weights used to calculate the gray value. The resulting grayscale pixel value will be a single number between 0 and 255, where 0 is black and 255 is white [4].

To convert an entire RGB image to grayscale using this algorithm, you can loop through each pixel in the image, calculate the gray value using the formula, and then set the pixel value to the resulting gray value [4].

quality lithophanes, while image processing algorithms such as the grayscale algorithm and depth map algorithm can be used to create lithophanes with varying levels of detail.

Hybrid 3D printing techniques, such as combining FDM and SLA printing, have also been explored for lithophane production, offering even greater potential for creating complex and detailed lithophanes.

The applications of lithophanes are wide-ranging, from decorative art pieces to medical imaging and education. Customized lithophanes can also be used to create personalized gifts or keepsakes.

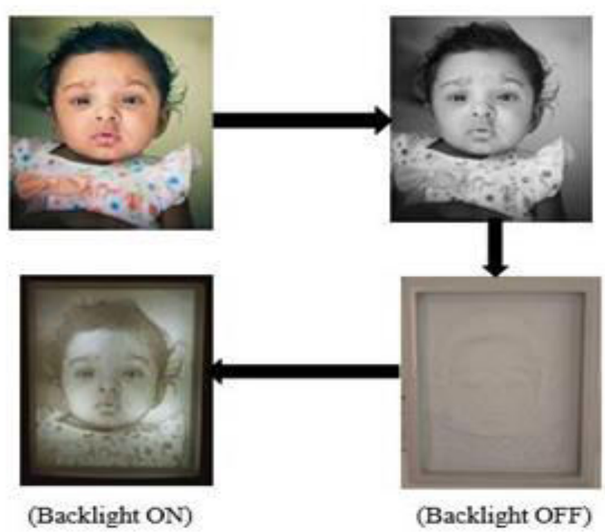

Figure 2: (b) Images representing step wise conversion.

The literature shows that 3D printing technology has greatly expanded the possibilities for creating and using lithophanes. More and more novel and interesting uses for lithophanes are anticipated to emerge as this technology develops further [4-12].

IV. CONCLUSION

The production of lithophanes has undergone a transformation with the introduction of 3D printing technology. This has allowed for greater flexibility and accessibility for artists and designers to create intricate and detailed lithophanes. The choice of 3D printing material, image processing algorithm, and hybrid 3D printing techniques have all been shown to impact the quality and aesthetics of the final product. Furthermore, lithophanes have a wide range of applications, including decorative art pieces, medical imaging, and personalized gifts. It is believed that as technology advances, we will see even more imaginative applications of lithophanes in the future. Overall, 3D printing technology has greatly expanded the possibilities for lithophane production, leading to exciting new opportunities for artists, designers, and innovators alike.

3D printing technology has opened up new avenues for the creation and use of lithophanes. Traditional methods of lithophane production, such as carving or etching, have limitations in terms of the level of detail that can be achieved, and can be time-consuming and expensive. 3D printing offers a more efficient and accessible approach, allowing artists and designers to produce intricate and personalized lithophanes with ease.

The choice of 3D printing material, image processing algorithm, and printing technique can all impact the quality and appearance of the final lithophane product. Materials such as PLA, PETG, and nylon have been shown to produce high-

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