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3D PRINTED LITHOPHANE

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Introduction

People are constantly creating and designing new works of art and objects. In the technological age, these creations can be transformed from the real world into the computer world and vice versa. We do all this to preserve art and cultural heritage, duplicate certain objects, render creations for easier presentation on computer screens and for many other reasons (Elkhuizen et al, 2019; Horne & Hausman, 2017; Koontz, 2003).
One of the ways to reproduce works of art is to convert them into a relief form and make a high-quality lithophane. Lithophane is a transparent plate on which an image is formed with the help of different thicknesses of this plate at certain points. Light traveling from the back of the panel through the panel displays a pure grayscale image on the front of that panel. The strength of the transparency is dictated by the material of the panel and the light source coming from behind, so called backlight. Without illumination from behind, the motif on the lithophane is unrecognizable (Lavelle, 2020).
The production of lithophanes experienced a revival in the 21st century with the entry of 3D printers into domestic households. To make lithophanes, we do not need much proficiency, however knowledge of 3D modelling and printing is required. 3D printing enables the production of lithophanes, as it can form a relief layer by layer (Zukas & Zukas, 2015).

Problem Description

The problem we wanted to solve was, to find out the best way to make 3D printed lithophanes, which parameters mostly contribute to visually pleasing motif and to refine them. Moreover, we wanted to make a coloured lithophane, so we had to research the best methods to colour the lithophane.

Methods

The structure of the process is shown in Figure 1 below. It shows how we started the work and how the steps follow one after the other. First, we devoted ourselves to the comparison of monochrome lithophanes with different parameters, and only then did we also analyse coloured lithophanes.

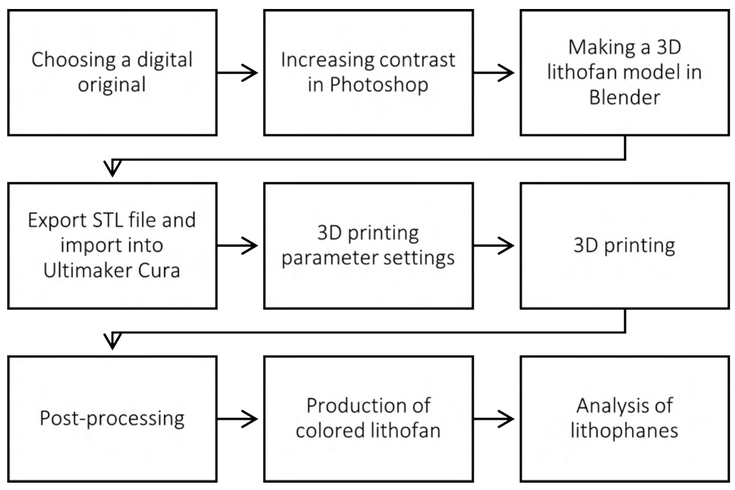

Figure 1
Procedure of experimental work

Results

Lithophane was printed in both horizontal and upright positions. For high-quality and accurate reproduction, we recommend choosing upright printing rather than horizontal printing, as the differences are significant and should not be ignored as shown in Figure 2.

Figure 2
Horizontal print (left) and upright print (right)

We continued by changing the thickness of the thinnest part of the lithophane (0.5; 1.0; 2.0 mm). Immediately visible difference is in the colour of the motif. The white polymer obtained a yellowish colour tone as the back thickness increased. The thinnest lithophane did indeed transmit light the best and printed the fastest, but the tile was simply too thin for our 3D printer, as artifacts showed up. The thickest lithophane let in too little light and yellowed too much when exposed to light. Thus, the winner was thickness of 1mm. Furtheremore comparison of different layer height settings and the quality of printing was researched. We compared layer heights of 0.12; 0.20; 0.28 mm. The results showed that the best setting was the smallest setting i.e., 0.12 mm, as the larger two settings produced visible layers in the motif.
Colour reproduction using the method with acetone was the worst. Too little colour transfered on to the lithophane consequently the colour on the illuminated lithophane is absent. The lithophane also deformed, as the reaction between acetone and polymer took place. The method of putting the paper behing the tile showed a good result, considering the effort involved, compared to the other methods. Mainly in colour saturation. The stars and blue sky are very beautiful, but in the darker parts, the details are completely lost and the subject becomes completely unclear. The best method is to use acrylic varnish. The paint on the back side of the lithophane lets in just enough light so that the details are not lost. That is due to the paper being removed from the back in the last step of the process. Although the colours are paler than with the first method, they are reproduced more accurately.
LED lighting is much more suitable for lighting lithophanes than a halogen lamp. Neutral white light is the most suitable for both monochrome and coloured lithophanes and does not change the colour tone of the polymer or the applied colours. Figure 3 shows a lithophane lit from the front instead of the back.

Figure 3
Lithophane lit from the front

Figure 4 shows the best litophanes from all of the above examples: upright; 1,0 mm; 0,12 mm; (acrylic varnish).

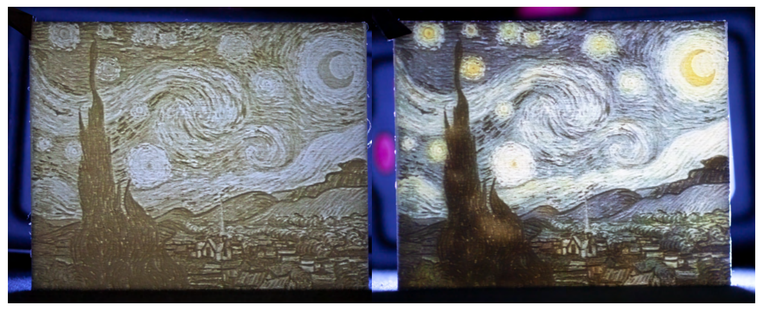

Figure 4
Monochrome lithophane - LED & Coloured lithophane - LED

Discussion / Conclusion

It turned out that the final image of the motif was most affected by the orientation of the lithophane during printing, where the upright orientation proved to be better. The back thickness and layer height also significantly affect the final quality. Where the 0.5 millimetre back thickness presented minor problems when printing, the 2.0 millimetre thickness stopped too much light when exposed. At higher values of layer height, longitudinal lines started to appear, which negatively affect the image of the motif. The results show that the best parameters are the upright orientation, the back thickness of 1.0 millimetre and layer height of 0.12 millimetres.
Findings in colour reproduction show that the easiest method gives satisfactory results, especially if the original image is lighter and brighter. The technique using acetone did not transfer a sufficient amount of colour to the polymer, to show the coloration of the lithophane. There was also deformation of the polymer. Method with acrylic varnish gives the best results. Here, the colour is well transferred from the sheet to the polymer. In this case, the image is the brightest, where all the details are visible, and sufficiently colourful.
In the last experiment we compared the LED light and the halogen lamp and the influence of colour temperature. It turned out that the halogen light emits too warm a light, thus causing the final motif to acquire an orange tone over the entire surface of the lithophane. The results show that the best reproduction of both monochrome and coloured lithophanes is achieved using neutral white LED lights. In both cases, we recommend lighting the lithophane in darker rooms if we want the motif to be seen as best as possible.
With the production of our lithophanes, we have shown that the 3D printer is a suitable tool for reproducing works of art in the relief form that is typical of lithophanes. With appropriate parameter settings we can produce high-quality lithophanes and if the lithophane is processed appropriately, satisfactory colour reproduction can also be achieved when using a neutral white LED light.

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