Optimized binarization for eggshell carving art

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CCS CONCEPTS

• **Computing methodologies → Image processing**.

KEYWORDS

Eggshell carving, optimization, binary image, carving art

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1 INTRODUCTION

It is amazing that something as fragile as an empty eggshell can be made into a beautiful piece of art. Egg carving is a delicate art form using precise tools to gently carve and cut away at the shell to form a three-dimension-surface model. This folk handicraft has gradually flourished in recent years. And in computer graphics, it is not only an interesting research field but also a potential industry product.

Given a color image and an eggshell 3D model, a new model can be generated in which surface mirrors the content from the given image after carving the holes. Finding the best fitted parts to carve is the key to generate a realistic carving 3D model. Yet, creating such master piece of carving 3D model from scratch is a tedious and time-consuming process that requires substantial expertise. To address this challenge, [Yang et al. 2019] preserve the image details by an optimal compromise between the black and white details. However, the images they get as input are the binary images. This prevents their method from challenging input images. In this paper, we introduce a framework to produce a carved model that is sculptured from an arbitrary color image. The designed objective function for optimization to generate the binary image from color image enables our system to produce visually pleasing eggshell carving results.

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2 OUR APPROACH

This study aims at generating the binary image of an input color image to guarantee that the details on output carving model are sufficiently connected, visually artifact-free and structurally strong for an eggshell carving artwork. In the generated binary image, the black details indicate the parts that are to be carved while the white details indicate retained parts after carving. Fig.1 illustrates the major processes in our system. Our system gets as input an arbitrary color image and 3D eggshell model. We first adopt the proposed optimized binarization to generate a tailored binary image for carving. This resultant binary image is mapped on the given eggshell model. Thereafter, the textured model is carved to generate the carving art.

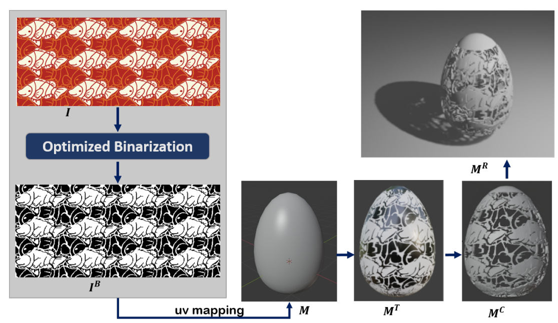

Figure 1: Our system overview

For the purpose of generating a tailored binary image, we design an objective function for optimization. To achieve this, we have two criteria. Firstly, important features in the input image should be preserved in the resultant binary image. Secondly, the remaining blocks after carving should be connected.

2.1 Optimized binarization

Given a color image, we segment the image into a several blocks. Each block consists of a set of pixels that have the same color and connected. We then construct a **Region Adjacency Graph** (RAG) from the segmented blocks. The RAG is used to generate the binary image through an optimization with three energy terms (1) *color difference*, (2) *area ratio*, and (3) *contrast*. Color difference is used to measure the differences between the color of the binary image and the input image. This terms is effective to preserve more tiny detail in the input image. Area ratio terms is to preserve the semantic structure of the input image on the 3D surface after carving. We control this issue by balancing the area of the black and white detail in the resultant image. In the cases that the color contrast of the adjacent blocks is high, contrast terms plays as a role to guarantee the high-contrast adjacent blocks are connected.

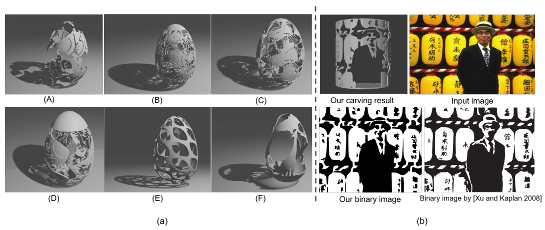

Figure 2: Our eggshell carving results with various input images. We compare with [Xu and Kaplan 2008] in (b).

After the optimization manner, we obtain an initial binary image. To guarantee all the preserved details are connected, we refine this binary image with a connectivity enforcement algorithm. To do this, we treat each white block as a node in a complete graph. We first find the isolated nodes in the graph. Each of them is then connected to the nearest node which is defined by a shortest path finding algorithm [Dijkstra 1959]. The ablation of this step is shown in Fig.3(b).

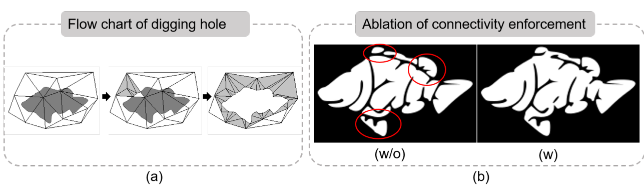

Figure 3: In (a), from left to right: the alignment of the pattern and the texture coordinates, the result of digging out a certain triangle mesh, and the result of digging out all the intersection triangle meshes.

2.2 Texturing and Surface Carving

Once the details in the image domain is defined, we map the image on the eggshell surface by calculating the intersection of the input image and the surface of the eggshell model. In this manner, we carve the black details textured on the eggshell model. Thereafter, we triangulate it to produce a new surface. The process of digging a hole for a fish shape on the mesh model is outlined in Fig.3(a). Note that that whole process is carried out on 2-D plane.

3 RESULTS AND CONCLUSION

In this paper, we propose optimized algorithm to generate the binary image that is tailored in the eggshell carving artwork. Our method can produce final carving model with high-sufficiently connectivity and structurally strong.

We exhibit our results in Fig.2 with different types of input images. Especially, the appealing result on Escher's artwork (Fig.2(B)), a gradual shape transition between different tile patterns [Lin et al. 2017], shows the ability of our method in generating visually satisfied carving results. Table 1 is the statistics of execution time on different input images and surface models. As shown in this table, the total execution time increases linearly with the number of polygons. Beside the experiments on eggshell model, we further demonstrate the ability of our method on other input images and other surface model as in Fig.2(b). As shown in this figure, the black details in our binary image are connected. Thus, it is sufficient to yield visually pleasing results.

Table 1: The statistics of execution time on different input images.

Fig.2	Binarization	Connectivity	# Polygon	Surface carving
(A)	0.034sec	2.643sec	7	5.492sec
(B)	15.593sec	4.155sec	264	217.768sec
(C)	6.025sec	8.034sec	129	85.209sec
(D)	15.221sec	890.913sec	128	49.997sec
(E)	0.026sec	0.013sec	145	5.202sec
(F)	0.313sec	0.020sec	19	0.995sec

Fabrication 3D models from the real world subjects are sometimes challenging to preserve the structure of the input image after carving due to the lack of a best-fit mesh parameters. Therefore, in the future, we expect to include more complex models in the real world. Besides, we hope to further improve our binarization to preserve more details such as the nose or mouth in the example of Fig.4.

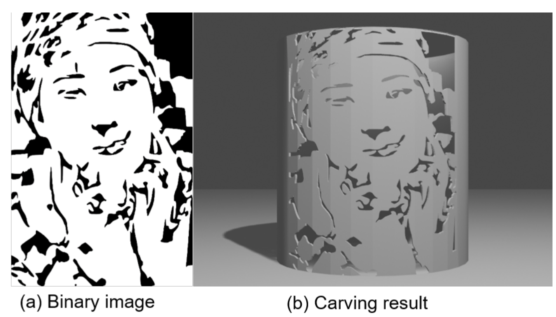

Figure 4: Our bad case.

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