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From Brush Painting to Bas-relief

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ABSTRACT

Among all forms of sculpture, bas-relief is arguably the closest to painting. We present a new approach for generating a bas-relief from a single 2d painting.We do not aim to recover exact depth of a painting, which is a tricky computer vision problem, requiring assumptions that are rarely satisfied.Instead, our approach exploits the concept of brush strokes, making each brush stroke possible to generate a correspond bas-relief proxies(depth map of strokes),used for bas-relief editing. To segment brush strokes in 2D paintings, we reformulate layer decomposition and stroke segmentation by imposing boundary constraints, which can make strokes smooth and complete. The resulting brush strokes are sufficient to evoke the impression of the consistent 3D shapes on bas-relief, so that they may be further edited in 3D space. This fulfills the request of recomposition in bas-relief design. Currently, our research focus on brush paintings with relatively sparse and clear strokes.

This accomplished part of the research leads to a few future works as well, such as,

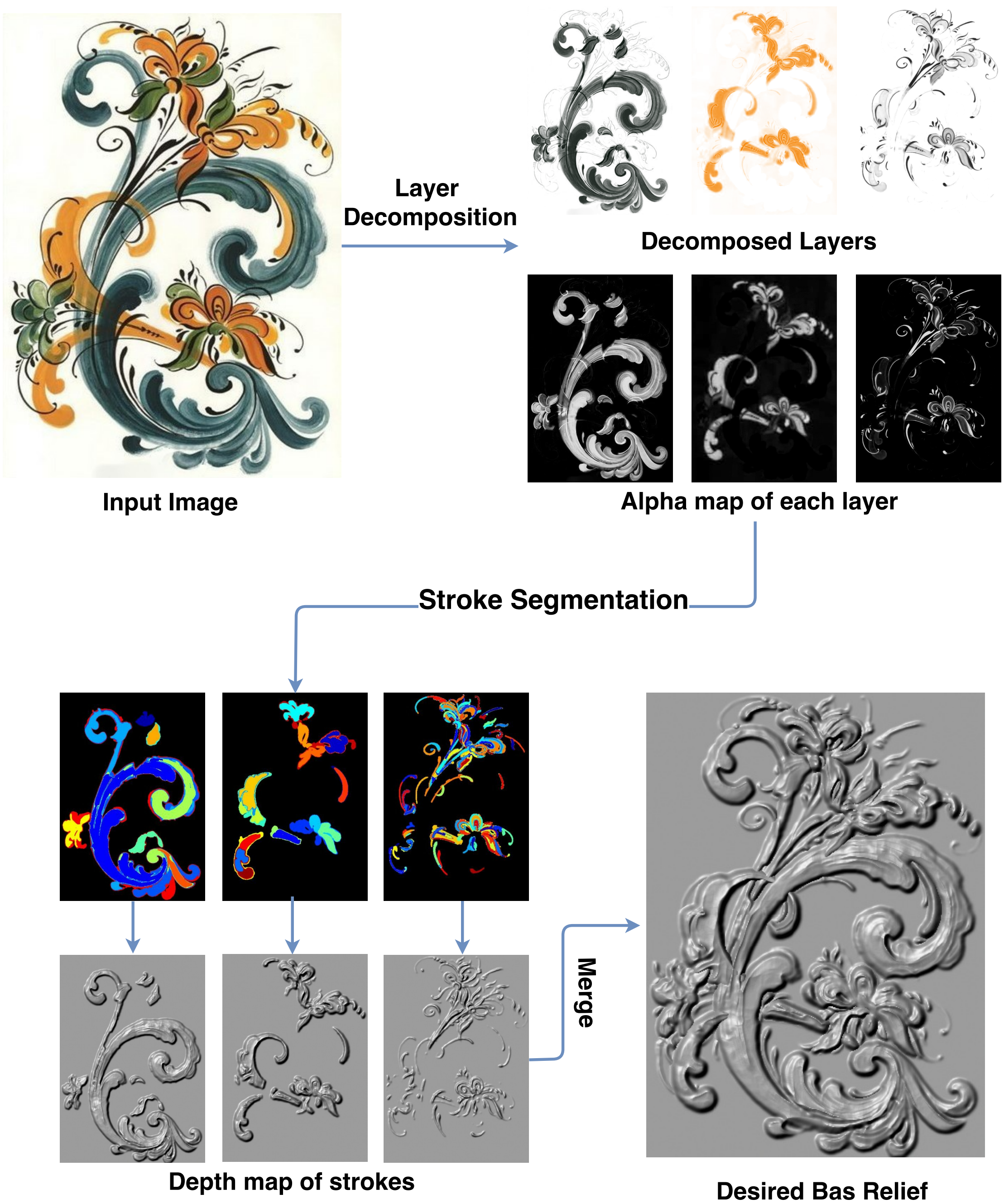

Figure 1: Pipeline Overview

Contents

List of Figures

Chapter 1

INTRODUCTION

1.1 Background

Relief is a kind of sculpture in which 3D models are carved into a relatively flat surface. As an artistic form, relief spans the continuum between a 2D painting and a full 3D sculpture [1]. Namely, it creates a bridge between a full 3D sculpture and a 2D painting[2].On this spectrum, alto-relievo (high relief) is closest to full 3D, whereas flatter artworks are described as basso-relievo (low relief, and also called bas-relief).And among all the sculpture forms, bas-relief is arguably the closest to 2D paintings [2].

As mentioned above, relief spans the continuum between a 2D painting and a full 3D sculpture [1].

How to generate bas-relief from 3D sculpture? Existing bas-relief production methods have demonstrate how to compress 3D sculpture(model) into bas-relief [1]and[2]. This approach requires a 3D model as a starting point.

On the other hand, how to generate bas-relief from 2D painting? There have been some bas-relief production approaches available based on 2D image in[3][4] and [5]. These approaches almost follow the "bas-relief ambiguity"[6], that is, roughly speaking, from a frontal view the sculpture looks like a full 3D object while a side-view reveals the disproportional depth. However, these image based method are focusing on general photograph, which unsuited for specific problems for brush paintings, such as stroke overlapping and its transparency.

Little is done in the area of bas-relief generation from artistic paintings, as maintaining the information of the brush paintings proves much trickier than simply manipulating the height of the contour lines. In the case of bas-reliefs, although there is no 3D model available, pseudo 3D effect reflecting the style and subtlety is crucial in preserving the artistic essence.

The aim of our research is to provide a new tool allowing user to convert existing brush paintings to bas-reliefs. We also argue that because traditional paintings are produced with individual strokes, '3D bas-relief strokes' will enable them to 'paint/sculpt' a bas-relief naturally, especially if they wanted to quickly convert an existing painting into a relief. With the commonly and cheaply available 3D printing facilities, there is a growing trend in the need of bas-relief art products.

A brush painting can be regarded as the union of a set of hypothetical strokes by a brush [7]. Differing from the other bas-relief generation methods, our method will honor this very feature by constructing the brush strokes individually as 3D geometric entities. This however demands to conquer several challenges. First, each brush stroke covers a region on the canvas and they may overlap each other, some quite heavily in a painting. To make sure the information is retained, every stroke has to be faithfully extracted. Second, spatial occlusion has to be dealt with, since artists are used to depicting it through controlling the transparency of strokes as one of the art elements. Third, as an artistic tool, the generated bas-relief should be further editable allowing the artist to rearrange, tweaking and reshaping the extracted strokes.

The shape, color and opacity of a stroke vary due to the shape and firmness of the brush as well as the forces the artist imposes. Although these variables add the complexity to stroke extraction, stylized strokes often follow distinct patterns. For example, Rosemaling paintings, a typical example of brush painting popular in North Europe, is a traditional form of decorative folk art that originated in the rural valleys of Norway. The Rosemailing designs use C and S strokes, feature scroll, flowing lines, floral designs, and both subtle and vibrant colors. The brush strokes may further be viewed as graphical objects which are meaningful with respect to the objects the painting portraits. Moreover, each stroke is clearly visible due to both subtle and vibrant colors. The similar properties may be found in some Chinese brush paints.

To extract the strokes from a brush painting, we need to identify and segment the overlapped strokes. We will then generate the depth map for every stroke separately using the shape from shading (SFS) technique on the opacity. All the strokes are finally merged together to yield the resulting bas-relief with the original 2D painting preserved.

1.2 Motivation

Bas-relief is an art form part way between sculpture and drawing. [3]

1.3 Contribution of Current Work

Our contributions include,
(1) Extraction of brush strokes. We develop a novel method to extract brush strokes from input paintings with palette analysis and decomposed layers.
(2) 3D modeling of brush strokes. We develop a novel method which may entirely construct every stroke to bas-relief based on the opacity of paintings.
(3) Recomposition in bas-relief design. Artists may redefine the brush strokes' order and shapes by sketches, which enable recomposition in bas-relief design, making it a useful tool for sculpture artists.

Overview As showed in Figure 1, the approach performs in three steps:

First, based on the point cloud of the input image in RGB space (Figure **??**),we select the palette colors of the input brush painting, and based on the palette colors we decompose a input image into different layers with transparency.

Second, the original painting is decomposed into element brush strokes by applying modified MSERs segmentation.Based on our observation, alpha map is more suitable for our MSERs segmentation, so the segmentation is based on the transparency. Third, based on the segmented brush strokes, Shape from Shading algorithm has been applied to generate the depth map of each stroke.

Finally, based on those depth maps of strokes , we can edit the generated bas relief. For editing,we have already generated the 3D proxies for each MSER region, namely, the extracted 2D brush region, so, we can change the depth of specific stroke on bas relief,we can also stitch them on each other based on the user input and change the shape of a certain stroke with given indicated skeleton. By doing so, we fulfill the request of recomposition in bas-relief design.The resulting 3D proxies of brush strokes are sufficient to evoke the impression of the consistent 3D shapes,so that they may be further edited in 3D space.

Currently, our research focus on brush paintings with relatively sparse strokes. Experiments show that our method can effectively generate digital bas-reliefs for a range of input images, including some Chinese paintings and rose-mailing paintings. We also demonstrate the utility of the resulting decompositions for image recoloring and image object insertion and animation.

1.4 Document Structure

Chapter 2

LITERATURE REVIEW

2.1 Stroke Segmentation

To the best of our knowledge, there is lack of study on extracting brush strokes from paintings. We give a brief overview of the work related to the relevant topics, i.e. decomposing images into layers and stroke segmentation, which are employed in our implementation. In digital image editing, layers organize images. However, scanned paintings and photographs have no such layers. Without layers, simple edits may become very challenging.

Richardt et al.[8] present an approach to produce editable vector graphics, in which the selected region is decomposed into a linear or radial gradient and the residual, background pixels . [9],[10]present two generalized layer decomposition methods, which allow pixels to have independent layer orders and layers to partially overlap each other.[11] present a layer decomposition method based on RGB-space geometry. They assume that all possible image colors are convex combinations of the paint colors. Computing the convex hull of image colors and per-pixel layer opacities is converted into a convex optimization problem. Thus, their method can work well without prior knowledge of shape and overlap of strokes.

Li et al.[12] describe a method based on seed growing for brush stroke segmentation.Starting from seed coordinates, neighboring pixels are visited by exploiting a region-growing-based approach with a variable threshold, which is initialized at a predefined and automatic updated by a shape validation method. But their brush stroke segmentation is limited to finding brush strokes in Van Gogh's paintings, and it does not support segmenting overlapped strokes.

Xu et al.[7] aims at decomposing Chinese paintings into a collection of layered brush strokes, with an assumption that at most two strokes are overlapping. And their approach requires a good amount of prior knowledge of shape and order of strokes.The segmentation of brush strokes is based on using a brush stroke library. While our method needs no brush stroke library, and our segmentation is based on multiple layers which more than two brush strokes could overlap each others(Figure **??**).

Most Stable Extremal Regions (MSERs) algorithm[13] has been proved to be a very efficient way in stroke segmentation from scene text images[14][15], and the revised version has been widely used in stroke segmentation of handwritten characters[16].

The Most Stable Extremal Regions (MSERs) algorithm[13] was used for establishing correspondence in wide-baseline stereo.[17] introduced the data structure of the component tree in it and further developed it as an efficient segmentation approach, which prunes the component tree and selects only the regions with a stable shape within a range of level sets, see Section 5.1.

However, it is likely that MSERs may fail in segmentation with the following scenarios,
(1) two adjacent regions with the similar intensity;
(2) the region with a high transparency.
(3) Moreover, like the other existing segmentation approaches, the MSERs algorithm encounters over-segmentation issue as well. To tackle these challenges, the coherent lines [18] is introduced into MSERs in our algorithm, which both enhances the edges of strokes and preserves the completeness of strokes, see Section 5.2.

2.2 Bas-Relief generation from 2D images

Automatic bas-relief generation from 2D image has recently become a significant research topic. Recently,researches have explored recovering depth information from images specifically for the purpose of generating bas-reliefs.

2.2.1 Gradient and intensity based methods

Wang et al.[19] demonstrate a method by constructing bas-reliefs from 2D images based on gradient operations. In their research image gradients was first calculated, then by smoothing gradients to smooth shape changes. Finally , they boost fine features by masks. The height image was constructed modified height map. The pixel heights are compressed, and a triangle mesh representing the bas-relief is determined by placing a vertex at each pixel position. By proposed algorithm most features can be preserve , but no con-

sideration is made for the overlapping relationship between different image regions, which is not suitable for brush paintings.
[20] present a two-level approach for height map estimation from the rubbing images of restoring brick and stone relief. The relief is separated into low and high frequency components. The base relief of the low frequency component is estimated automatically with a partial differential equation (PDE)-based mesh deformation scheme. The high frequency detail is estimated directly from rubbing images automatically or optionally with minimal interactive processing. This method works well for reliefs based on brick or stone, but is unsuited to general photographs or brush paintings.

2.2.2 Shape from shading(SFS) based methods

Some work uses Shape from shading for generating bas-relief from 2D photograph. SFS is a relative classic way for 3D shape recovery; see Zhang's survey [21]. The computation process normally involved with several concepts : depth $Z(x, y)$, surface normal n_x, n_y, n_z ,and surface gradient p, q. The depth can either be considered as distance from viewpoint to query surface or the height from surface to default $x - y$ plane. The normal is perpendicular to the surface gradient, namely $(n_x, n_y, n_z) * (p, q, 1)^T = 0$, the surface gradient is the changing rate of depth in x and y direction.

Shape from shading (SFS) is able to recover the shape of an object from a given single image, assuming illumination and reflectance are known (or assuming reflectance is uniform across the entire image). Many methods have been developed, which may be categorized into four PDEs models[22], (1) orthographic SFS with a far light source [23]; (2) perspective SFS with a far light source[24]; (3) perspective SFS with a point light source at the optical center[22]; (4) a generic Hamiltonian. However, SFS is an ill-posed problem. The notable difficulty in SFS is the bas-relief ambiguity[6], that is, the absolute orientation and scaling of a surface are ambiguous given only shading information. To amend it, many SFS algorithms impose priors on shape, depth cues produced by a stereo system, or assume that the light source, the surface reflectance, and the camera are known[21]; [25]; [26]; [27];

Unfortunately, SFS based methods is assuming illumination and reflectance are known, and the image is formed from lighting and shading, which works well for realistic photographs rather than paintings.

2.2.3 Line drawing based methods

Rather than generating bas-relief from a photograph,some researches start with line drawings. Kolomenkin et al.[28] aims to reconstruct a model from a complex drawing that consists of many inter-related strokes.At first, they extract the curves from the image of the drawing.Then,junctions are detected and margins are generated. By analyzing the connectivity between boundaries and curves, they reduce the problem to a constrained topological ordering of a graph. From these boundaries and curves with given depth, they use smooth interpolation across regions generate the bas-relief surface. Similarly,line labeling methods has been applied for shape construction from line drawings [29][30][31]. A labeling process would classify segmented lines into different labels, such as concave, convex and occluding, and these labels can give clues for the shape generation of bas-relief.

But line drawing based methods are limited to using information contained in a line drawing,which is not suited for brush strokes which contain information such as color,transparency and stroke shape.

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