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A Review on Computer Assisted Techniques Used in Relief Generation on Artistic Surfaces

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Abstract

This paper reviews the various computer assisted techniques used in the relief generation on artistic surfaces. Relief is sculpture artwork which is partially carved into or out of surface with help of hand tools. Today, the use CAD is more and more being used in traditional work. Based on methods relief can be generated on by three way as: direct modeling, transforming 3D data and image based relief generation. Recently, development in design tools provides automatic or semi-automatic relief generation algorithms that allow users to create relief of commemorative objects. CAM tools offers a new level of variation to the fabrication/manufacturing process.

Keywords: Bas-relief, high relief, sunken relief, CAD/CAM

1. Introduction

Relief generation is kind of traditional sculpture artwork which is partially carved into or out of same surface with help of hand tools, represents as single pieces of artwork and used as decorations. A relief is different from painting and drawing in sense that we can illustrate a virtual 3D form in 2D space, representing the same details that 3D sculptures have. These sculptures rely on background surface, by process of carving shapes out of the surface using knives and other sharp tools. Reliefs represent combination of both three dimensional and two dimensional art forms. Relief generation find their application in ornaments, wall decorations, statues, carvings etc. Relief sculptures are categorized as depending on depth of carving as:
High relief: In this types of sculptures forms undercutting of design elements is so they appear to detach from the background space.

Bas/Low relief: bas/low relief has less depth on faces and has suitable scenes with a minimum extent from background giving a impression of raising from surface.

Mid relief: mid relief lies in between bas and high relief.

Sunken relief: a sunken relief sculpture is carved inside the surface, rather than out of it.
The relief work is laborious, challenging and time consuming process that has the drawbacks of lacking a preview option and being hard to correct or replicate with regard to large-scale manufacturing. Today, the concept of the CAD has made rapid development in the field of handicraft sector. The use of the computer in a designer/maker practice is not changing the

fundamentals of the concept of the craftsman; instead this should be seen as an opportunity to develop traditional skills with new processes and aesthetics.

(a) (b) (c) (d)

Figure 1:Relief Sculptures (a) High Relief (b) Mid Relief (c) Bas Relief (d) Sunken

Using recent technologies in CAD/CAM, computer numerically controlled (CNC)/RPT manufacturing turns virtual model to a physical objects rapidly. For the traditional crafts, a combination of traditional skills with high-end new technologies is required (G. Renda). Today, craftsmen can use the digital relief as a reference or as a preview for carving result (Wang, 2010). This paper presents a review of computational tools and methods today used for automated relief generation. Based on modeling techniques there are three main methods to generate the relief as: direct modeling technique, image based relief generation and 3D shape to relief.

2. Practice of Relief Generation

A relief sculpture may specialize by material as wood, clay, stone or metalwork, the art of relief is not identified by a particular craft. The sculpture may be produced by techniques of material removal (wood/stone), by material addition (clay/plaster, paper-mache) or by casting (metals). In carving practice, the relief sculptures are produced by removing material in the direction of depth with the help of hand tools as shown in (fig. 1). On curved surfaces, the carving direction is parallel to surface normal. Many types of tools, differs in size and shape are used to create different surfaces such as flat, grooved or round and so on. The depth of cut is controlled by slant angle of chisel and hand push.

3. Direct Modeling Tools

Today, all the CAD tool are build for the industrial environment and have very power full capacities in solid and surface modeling. There are many design tools are available in the market such as 3DS MAx, Maya, Photoshop, Zbrush, Pro-e, Solidworks etc. The relief generation in these packages is done by direct manipulation of the sketch geometry or image similar to part modeling. Photoshop use gradients to generate bas relief of low height for melting surfaces, ripple surfaces, distorted surfaces, mountain range surfaces and more. Z-brush provides the more functionality to user with various adjustable tools that mimic the actions performed manually by the artist, such as brushing, smoothing, and pinching. Art CAM generates the reliefs by direct manipulation of geometry. The current CAD systems for industrial application are not suitable for relief generation and require greater knowledge of tools for modeling complex designs.

Sourin (2001) developed an interactive shape modeler in which the functional model is modified from initial with offset and set-theoretic operations which simulate the different embossing operations. These software tools are especially designed for art patterns with a library of templates for users to choose vector images which does not require modeling again. Relief carving is modeled by offsetting along normal and offset value is defined by the depth data (Wu

Jing, 2013) . Depth data is used to carve a arbitrary solid model to generate relief model. A modeling by tool for generation of relief object is presented by Bourguignon et al. (2010). Relief modeling of an object is carried out in two steps: in first step, the user trace out in image space; in second step, the tracing information is used for moving or creating surface vertices. This information is also used for pushing or pulling vertices of existing surfaces, or for creating vertices of new surface patches which are automatically positioned in space.

4. Image-Based Relief Generation

The image based relief generation is widely used to generate bas relief as it almost a plane surface and requires preservation of small details without destroy the shapes. From the high-resolution images of original painting, a carving result can be produced by using the method described by Reichinger et al. (2011). Using this method one can generate RPT data quickly from painting image to produce the physical object by adding depth relation. A relief carving technique from an image in which color of each point defines the elevation corresponding 3D point is developed by Chua et al. (1997). Edge detection filters are used to extract edge from images and 2D representation of edges converted into a 3D model (Schweikardt, 2000).

A semi-automatic tool for creation of bas relief from virtual scenes is developed by J. Kerber at el. (2009). This work uses a filtering approach to preserving curvature extreme during the compression process and to handle complex scenes with fine geometric detail. The image is normalized for a smaller foreground value mapped to background, ranges from 0 to certain value. Brick and stone relief surface consists of two levels: base relief, refers to low frequency and high frequency detail which refers to small local features (Li, Z et al. 2012). The object contours are detected first, and then skeleton, to create rough structure. 2D image contains regions, boundary, textures information corresponding to 3D scenes (Zeng et al. 2014). Region-based layer are determined by extracting 2D feature line from input image which give information about segments, regions, junctions and relationship between them using a two level graph (fig. 2). For relief generation the height values are used to constraint base surface. Jingsong et al. (2007) developed Evolutionary algorithms (EAs), that can be applied to the real world application to produce the attractive results as there is less constraint of knowledge of applied domain.

A automatic relief generation algorithm is developed to produce bas relief from the pair of images under different illumination in a single piece of art (Alexa and Matusik, 2010). The model is proposed, corresponds to pixel value and least squares optimization is used to determine discrete surface. Chen et al. (2011) presented an algorithm for relief extraction and editing from a mesh. Relief is extracted from a background surface as it is offset relative to underlying base surface. Extraction is performed by estimating smooth normal's and reconstruction by Poisson equation. A two step based approach to generate bas relief of human face from image is presented by Pasko et al. (1998). In first step a plausible image is generated of the face and secondly, shape from shading is applied to generate the 3D shape of relief. Two relief surfaces are generated using different lighting directions and average surface is taken as output. After generating the relief surface, SFS is applied to generate final 3D model of bas-relief.

5. Relief from 3D Models

Today, 3D modeling application area is moving outside from traditional area of application such as car, movies, industries, reverse engineering etc., now it is also growing leaps in new fields. A 3D model contains large information content which can be further processed in computer graphics for interactive or virtual representation. A 3D scene can be represented in numerous ways as polygon mesh, depth map, level set and vowels. A method to generate sunken relief from a 3D object using a line extraction is presented by Wang et al. (2011). The line information is

pre-processed to smoothen the results and by the line information, mesh of 3D relief can be generated.

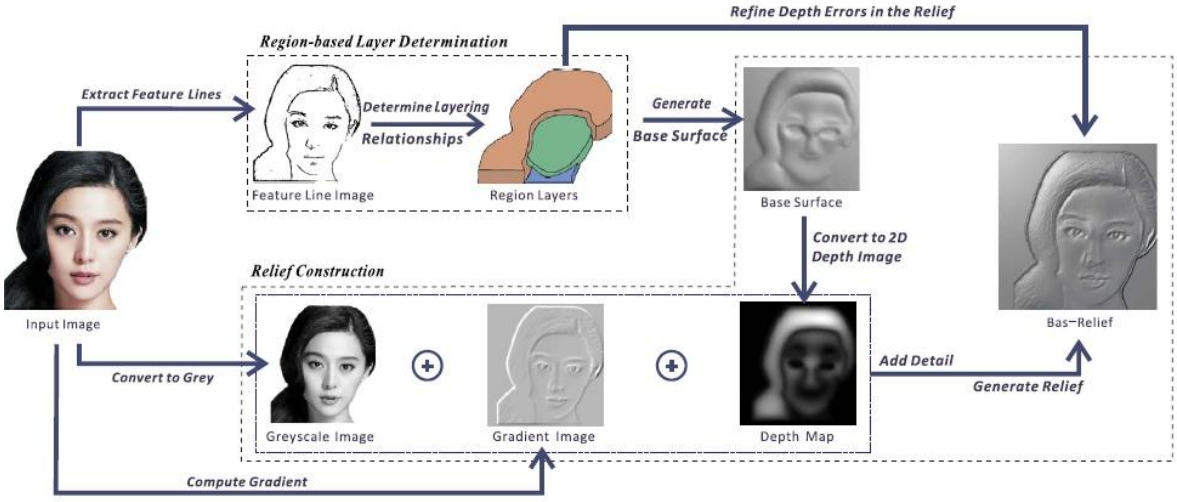

Figure 2: A framework for region-based layer determination and relief construction

Figure 3: Automatic feature based bas-relief generation from 3D scenes by J. Kerbar [10]

Cignoni et al. (1997) developed a public-domain software tool using visible surface determination algorithm for bas relief and high relief generation from 3D surface models. The algorithm returns a 2D subdivision of the view plane into visible polygons. Each pixel of the z-buffer holds the z-coordinate of the corresponding pixel of the visible surface in the rendered image that corresponds to depth value computed by the perspective transformation. By the 3D scene or CAD model, relief can be produced by using adaptive histogram equalization. Histogram equalization is applied to uniform the intensity of image, maximization of entropy results in improving the contrast. Height field can be generated by using the visual surface determination to remove unused depth intervals to clear the scene (Sun et al. 2009). The two value of height field is determined to move scene towards background to minimize relief height. Belhumeur et al. (1999) investigated the ambiguity of bas-reliefs generation with respect to surface reconstruction. An ambiguity in determining the object's geometry arises if there exist other objects that differ in shape can produce the same set of images. The 3D shape can be converted to bas relief object by using high-dynamic range compression method developed by Song et al. (2007). The concepts of mesh saliency, shape exaggerating, and discrete differential coordinates is combine and used in the shape bas relief. Using this method, the salient features are preserved as original shape and can be used for decoration. A Markov Random Field (MRF) approach is used to generate the

surface relief using height field rather than depth map (Vogiatzis et al. 2008). Base surface is defined by a dense sent of points with a fixed normal direction. Height filed of point is generated by belief propagation technique and in this the parameterization of scene is general.

Two methods for automatic bas-relief generation from 3D digital shapes are presented by J. Kerber et al. (2010). In range domain approach, bilateral filter is used for edge-preservation to extract the base layer of the shape and filtering is done by product of Gaussian Kernels. Laplacian operator is used for image denoising and gradient domain also uses as bilateral filtering. A semi-automatic system for production of bas relief from digital 3D models is developed in (Bian and Hu, 2011). Before compression height field are processed for reducing height gaps and Laplacian coordinates are used to restore features after compression. The relief height is computed relative to background with Poisson equations. The reliefs can be attached to new background by setting boundary points to new values.

A framework to produce sunken reliefs from a 3D mesh/geometry is presented by Wang et al. (2011). Sunken relief is transformed into the surface using contour lines into three layers which contain geometric information of relief as shown in (fig. 4). Sunken reliefs utilize line drawings information (Zeng et al. 2005) to create feature lines, Lambertian shading image and depth map; together to produce smooth relief.

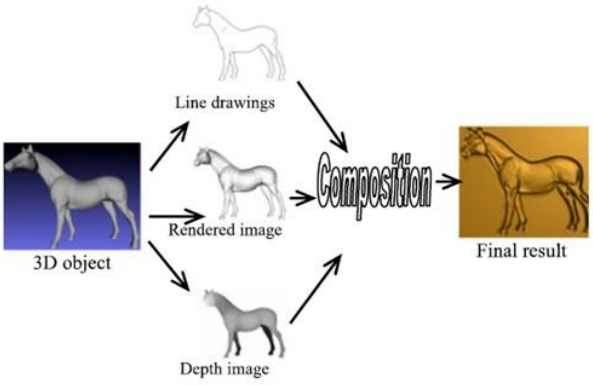

Fig. 4: Producing Sunken Relief from 3D

6. Relief Generation Using Shape from Shading

Shape from shading allows surface recovery from an image without any additional data (Prados et al., 2005). Human eyes are able to perceive the objects, their physical and chemical properties, from scattered radiations towards eyes. Shape from shading is used to generate 3D scenes from one or more 2D images or 3D model. The results can be represented as surface gradient, surface normal, surface slant or depth Z. The depth can be considered either as the relative distance from camera to surface points, or the relative surface height above the x-y plane. Gradual variation in shading of image is used to recover shape in SFS by Zeng et al. (2005). There are four main approach in SFS as; propagation, minimization, local and linear. In a propagation approach shape recovery is done by propagating the information of shape over some reference points. Minimization approaches compute the solution which minimizes an energy function over the entire image. The function can involve the brightness constraint and other constraints, such as the smoothness constraint, the integrability constraint, the gradient constraint, and the unit normal constraint. A approach to reconstruction of surface normal from single image is presented by Wu et al. (2008). The shape from shading is improved to reconstruct the local region and then amplified low frequency errors. Local approaches derive shape based on the assumption of

surface type. Linear approaches compute the solution based on the linearization of the reflectance map. Height fields describe the relief surface from the base and calculated by belief propagation technique (Vogiatzis et al. 2008). A reverse engineering method for Fatimid art is presented by Morero et al. (2013). A non-destructive method is used for taking impressions of details of the surfaces of the artifacts by applying a light bodied silicone rubber which flows freely into the carved and polished recesses and, when removed, preserves its original shape.

7. Conclusion

Today, the use CAD is Computer aided design is more and more being used in traditional work for generating artistic objects. This work reviewed the computer assisted relief generations methods. Relief generation using direct modeling tools can produce quality reliefs and result produced depends on knowledge of designer, but this method is laborious and time-consuming. Compression method produce a fine result by transforming 3D models to mid or reliefs. Height field data is generated from 3D models and then some image processing method is applied to produce relief model. In the relief models, the scene depth is preserved through combination of feature information and shading. Today, automatic and semi-automatic tools are developed to generate the relief from images and virtual scene using filtering and feature extraction approaches. The final relief generated contains real height information and can be directly used in CAD/CAM systems. Today, these technologies should be used to preserve the cultural heritage and traditional art/crafts and to speed up the design and manufacturing of traditional crafts.

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