

Robotic Rendering of Oriental Ink Paintings with Spatial Awareness

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Abstract—Enabling robots to imitate artists who observe objects in the 3D world and physically draw them in a specific style is a challenging problem. *Shuimohua* (*Sumi-e*) is a typical non-photorealistic oriental ink painting art that uses simple ink, water and brush to paint and convey poetic imagery. Although digital rendering of non-photorealistic paintings has been extensively studied, physical rendering of stylized painting from 3D space is still a challenge because it requires to consider the abstraction process of vectorized strokes with various styles in physical environment. In this paper, we propose a robotic rendering approach for physically drawing oriental ink painting from 3D shapes, and aim to mimic the painting process of a real-world artist using binocular vision to estimate 3D scenes. By referring to the artists’ drawing habit, first, we extract expressive contours as drawing outlines and vectorize the contours to polylines. Next, the polylines are converted to line strokes with varying thicknesses by considering clamped B-spline fitting and isophote distances. In order to generate a typical dot shading effect, an oriented Poisson disk sampling approach is proposed to create dot strokes to depict the internal features of the 3D Shapes. Finally, we build an ink gradient model and map the coordinates of the strokes to a robotic arm, and a control method of guide rails is proposed for robotic painting on large canvases.

I. INTRODUCTION

Oriental ink painting (also termed as *Shuimohua* in Chinese [1] and *Sumi-e* in Japanese [2]), as a traditional art form, is beloved and highly favored by Asian people, particularly in East Asia, because it not only represents a cultural symbol but also reflects the local religious (such as *Daoism*) and philosophical beliefs (such as *Zen*).

However, *Shuimohua* presents unique challenges that distinguish it from Western painting techniques in many aspects such as material sensitivity (e.g. Unlike oil or acrylic, *Shuimohua* deliberately uses rice paper to absorb ink) and reductionism (e.g. Unlike Western additive processes, *Shuimohua* follows “subtract until only the essence remains”), that poses steep learning curves for the beginners. Therefore, with minimal user intervention, employing robots to analyze the abstract techniques of orient ink painting and physically render artworks on canvases according to users’ preferences presents both a practical and engaging endeavor. In this paper, we propose a robotic rendering approach for drawing *Shuimohua*-style painting on a rice paper from 3D shapes. We adopt 3D shapes over 2D images primarily for two reasons: (i) *Shuimohua*-painters usually utilize binocular



Fig. 1: Two masterpieces of dot style painting. (a) Mi-dot style painting “Spring Mountains and Auspicious Pines” by Fu MI (1051–1107 CE); (b) Point painting “Petit Port de Bacon” (1917 CE) by Paul SIGNAC.

disparity to acquire depth perception in 3D space when depicting landscapes; (ii) From a computational standpoint, 3D shapes contain superior geometric information (normals, curvature, luminance, etc.) essential for authentic brushstroke drawing. Fortunately, with the rapid advancement of 3D vision, graphics, and AIGC technologies, acquiring 3D shapes of real or virtual worlds has become increasingly convenient and effortless.

Recently, Jin et al. [3] first designed a robotic painting framework to draw stylized contour strokes from 3D models. However, they haven’t considered the spatial surface shading/texturing effects for *Shuimohua*-style painting. The surface shading/texturing techniques are termed as *CUN* which first emerged during Tang Dynasty of China (618–907 CE) [4]. Before the Tang Dynasty, *Shuimohua*-style painting was dominated by figure paintings, which mainly relied on contours or outline strokes. Since the landscape painting of Tang Dynasty was separated from figure painting, the painters combined their observation of nature and personal artistic understanding to summarize the shading or texturing techniques (*CUN*) that can express the surface of mountains, rocks and trees. Ji ZHENG [5] systematically categorized 16 distinct *CUN* techniques in oriental painting. However, stripping away the dynamic brushwork factors and only performing visual morphological analysis, the *CUN* techniques can be divided into three categories: dot, line and surface styles. Among them, the line style is mainly used to express the contours of the drawing object; the surface style is mainly used to express the texture of the painted object with a flat surface; and the dot style is able to draw the painted object with various surfaces, therefore dot style demonstrates broader applicability compared to other *CUN*.

Fig. 1(a) shows a typical masterpiece of Fu MI’s dot style *Shuimohua* painting. Coincidentally, Western arts developed

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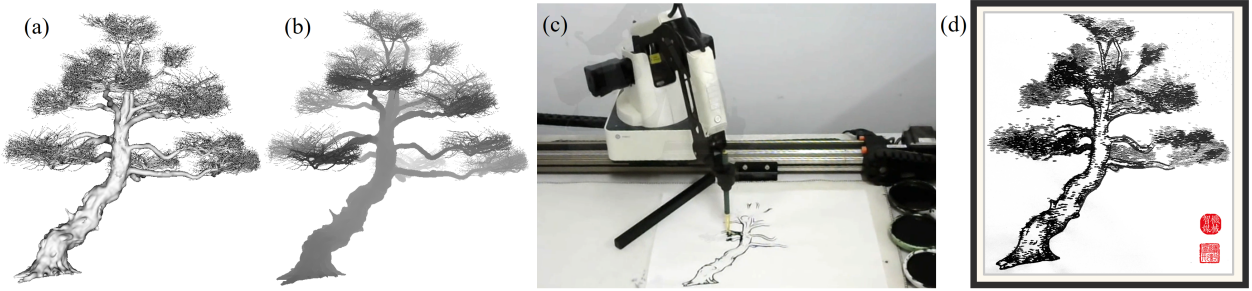


Fig. 2: Input a (a) 3D model containing (b) depth information with an arbitrary viewpoint, our painting robot is able to understand the spatial information of the input and render an (c, d) oriental ink painting on a large canvas.

a parallel technique to dot style painting—Pointillism [6], pioneered by French artists Georges SEURAT and Paul SIGNAC (see Fig. 1(b)) around 1886 CE. Despite nuanced differences in colors, shapes and density of dots, both *CUN* techniques and Pointillism fundamentally harness the basic power of dots—the most elemental artistic unit—to convey the artists’ philosophical ideas.

In summary, the dots serve as a fundamental and representative brushstroke in painting, and the tedious and time-consuming dotting operation particularly well-suited for robotic automation. Therefore, we focus specifically on rendering large dot style *Shuimohua* paintings using robot guide rails (see Fig. 2). The contributions of this paper can be summarized as follows:

- We propose a spatially-aware robotic rendering method for physically drawing large-size *Shuimohua* style paintings with guide rails by considering both the contour strokes and the inner dot texturing/shading strokes.
- Instead of using interactive editing of contour strokes [3], we introduce an automatic and efficient stroke vectorization and generation method by considering skeleton-based merging and splitting, clamped B-spline fitting and isophote distances.
- We present a dot shading method for drawing artistically faithful inner strokes of *Shuimohua* paintings by employing signed distance field and a dart throwing-based Poisson disk sampling method.

II. METHODS

Fig. 3 shows the workflow of our robotic rendering system. Input a 3D model with depth information, we first extract and simplify expressive contours using a deep learning-based method. Then, a fast skeleton-based method is utilized to vectorize the contours. Next, line stroke thicknesses are generated by using clamped B-spline fitting and isophote distances. Meanwhile, the inside dot strokes are created by introducing Signed Distance Field and a dart throwing-based Poisson disk sampling. Finally, we control the robot with a guide rail to draw both the contour strokes and dot strokes flexibly by taking account of ink intensity and brush softness.

III. RESULTS

Our robotic drawing framework was implemented in a PC configured with a 4.0GHz CPU, 16GB RAM, and Windows

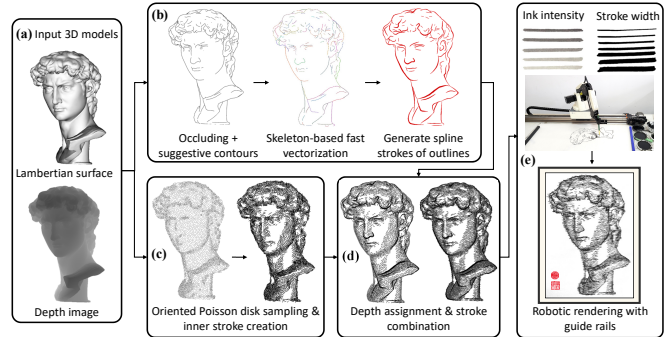


Fig. 3: Overview of our robotic rendering system.

10 OS. A consumer-grade robotic arm “Dobot Magician” with a guide rail (less than 3000\$) is used to draw various oriental ink paintings. A number of robotic rendering results from 3D models including humans, rocks, mountains and trees are presented to demonstrate the effectiveness of our approach as shown in Fig. 2 and 4.

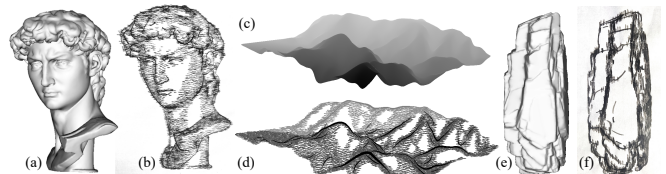


Fig. 4: Painting results of our robotic rendering system. (a,c,e) Input 3D models; (b, d, f) Painting results.

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