Mural2Sketch: Line Drawing Generation Methods for Mural Paintings

Aditya Mittal
aditya18061@iiitd.ac.in
Indraprastha Institute of Information Technology, Delhi

Meenakshi Maindola
meenakshi18081@iiitd.ac.in
Indraprastha Institute of Information Technology, Delhi

Shubham Gupta
shubham18055@iiitd.ac.in
Indraprastha Institute of Information Technology, Delhi

Shiven Mian
shiven15094@iiitd.ac.in
Indraprastha Institute of Information Technology, Delhi

ABSTRACT

Mural paintings form an integral part of art heritage around the world. Therefore, a computational method for producing sketch from murals is meaningful and essential in mural copying and cultural research areas. Mural2Sketch (MS) proposes a line drawing or sketch generation algorithm for ancient mural paintings. At first, noise reduction is performed on original mural images. Then, the algorithm uses both outer edge detection information generated by heuristic routing and the inner stroke information produced by high-frequency filters. To produce effective results, we further perform stroke optimisation. Experimental results show that our method produces clean and smooth sketches even with noisy murals.

Keywords: Murals, Sketch Generation, Edge Detection, Inner Stroke Extraction.

1 PROBLEM STATEMENT

We aim to develop a novel framework for line drawing or sketch generation of ancient mural paintings.

2 INTRODUCTION

A mural is a piece of painting or artwork which is made directly on the surface of a wall, ceiling or any other permanent surface [6]. Most of the ancient murals have been created using line drawings also known as a sketch. Line drawing uses distinct straight and curved strokes/lines for creating objects and expressing ideas.

The murals have been damaged by several natural factors like climate, humidity and ultra-violet radiation. Mindless vandalism and carbon dioxide exhalation by humans contribute equally to this cause. One of the methods used by painters to preserve the mural heritage is the manual copying of mural paintings. However, this method is performed in low lighting conditions inside caves and is thus inefficient, error-prone and lacks accuracy. In addition to this, the manual process is time-consuming and susceptible to the painter's skills.

An up-gradation to the method of mural copying was introduced when photography was considered as a suitable option. Painters tried to copy mural paintings by digital mural pictures, but the complete process is still time-consuming and complicated. With time, the murals are getting damaged, faded and lost. So, this method of digital mural copying also proves to be inefficient and slow. Therefore, it has become important to digitally curate these paintings and extract sketch of ancient murals using computational methods.

Figure 1: A mural eyebrow drawn by one stroke and a digital illustration extracted by edge detection.

Our project works on the implementation of a mural line generation algorithm named Mural2Sketch (MS). It performs an outer edge detection process by heuristic routing, and then inner stroke extraction is done by high-frequency enhancement filtering. Further, the categorisation of pixels in the mural image is done into two categories: stroke objects and non-stroke objects. Selecting the pixels of a mural image that lie in stroke object is termed as mural stroke extraction. Let x_p be a pixel value of pixel p in image I. They defined a stroke detector $D(x_p)$ as follow:

$D(x_p) = 1$, if p belongs to stroke objects
$D(x_p) = 0$, if p belongs to non-stroke objects

They use both outer edge and inner stroke information to find an optimal detector $D(x_p)$ for line drawing generation.

3 LITERATURE SURVEY

Sketch Generation is not a newly introduced problem in the field of Computer Vision and Image Processing. Several kinds of research have been proposed in the past in this field. However in our knowledge, edge detection or sketch generation techniques are mostly used for facial images or natural images. The ancient murals have specific stroke design, background knowledge, and artistic style which must be considered to produce better results.

J. Liu et. al. [3] first find the contour line which made up of many connected curves of a Dunhuang fresco (murals painted on a wet wall or lime plaster) and then renders the strokes by learning styles from examples to interactively generate the sketches. But getting the contour line is time-consuming and it would be more desirable that it would be tracked automatically. Also, they do not

consider the feature brush texture which can play an essential role in improving the results of mural sketch generation.

Another is the early work of the authors of the paper we are referring to [2] who proposes a computational fresco sketch generation framework which uses fresco as input to extract sketches. This framework consists of four major components described below:

(1) Hierarchical Structure Segmentation: This method is used to extract the frescos structure from the input image. It has further two stages which include:
   - Globalized probability of boundary(gPb) based feature extraction
   - Closed region generation.

   After this, the user is allowed to divide structure blocks into sets as to get different sketches using different parameters.
(2) Sketch Generation: In this component of the system different sketches of the divided blocks are obtained and put together to form a single image.
(3) Missing Content Replacement: The output sketch from the sketch generation phase contains an incomplete line. Therefore, in this component, a feature descriptor database is created using existing frescos and a function for finding and replacing missing content is used.
(4) Sketch Optimization: Uses a polygon tracking algorithm introduced in the paper itself to optimize the sketch by reconstructing the vector representation of the sketch.

The authors used Chinese Dunhuang Mogao Grottoes Frescos as Dataset. The resulting sketches are compared with existing copied sketches painted by painters and the results show that better sketches are generated using the system than those painted by painters. However, the sketches generated by the framework, contain incomplete lines. Also, the framework is valid only for frescos and does not consider other mural painting techniques.
There are several methods for edge detection, Canny [4] proposed a detector which uses adaptive thresholding along with hysteresis to eliminate streaking of edge contours. First, the noise estimation scheme determines the amount of noise in the image and then the threshold is set depending upon the amount of noise in the image. Several operator outputs are combined together using feature synthesis in order to describe the edges at different scales. But the feature extracted from these operators will generate two lines around one stroke because mural strokes usually have a certain thickness. Hence we need to specialize in sketch generation technique for ancient murals.

4 DATASET

The task of line drawing from murals is purely based on image processing techniques. We just input a mural image and draw its sketch. It does not require any ground truth as it is not a classification problem. Also, this work does not require any specific data-set of images which have annotations.

We have used a data-set of 10 images. Out of these ten images, five images are used by [1] and the rest were found from internet sources. All the images are murals images.

5 STATE OF THE ART DESIGN

The most recent work in line drawing generation from murals is done by [1]. They used the information of both the outer edge and inner stroke. The outer edge is detected by heuristic routing and then high-frequency enhancement filter is used to extract the inner stroke information. The results obtained from both the methods are integrated and optimization is performed to produce the final output sketch.

The flowchart for proposed algorithm is shown in Figure 1 and is discussed in detail below.

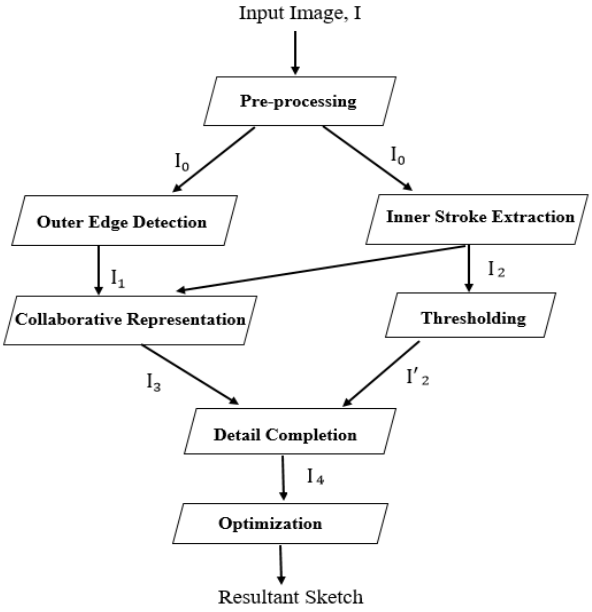

Figure 2: Flowchart of Mural2Sketch

5.1 Pre-processing

The paintings are damaged and faded due to natural and human factors. If sketches are directly generated from original mural images, it would involve a lot of noise. Therefore, we have applied L0 smoothing method [7] in order to remove unnecessary details and refine detail lines from original mural images. To make stroke extraction easier, gray value of background pixels is simplified. This is done by convolving the image with 5x5 Gaussian kernel. This results in maintaining the contrast between stroke and background which in turn suppresses the noise in the image.

Figure 3: The image shows the original image and image after noise removal i.e. the pre-processed image.

5.2 Outer edge detection with heuristic routing

The pixels having a high probability of being edge elements are referred to as anchors. These anchors are extracted and connected through heuristic routing. Canny operator [4] is used set pixels as anchors. It is also used to obtain Gradient magnitude and edge direction maps for efficient routing process.

The routing process connects the anchors by drawing edges between them as follows: if a horizontal edge passes through an anchor then the connecting process starts either from left or right, depending on the gradient magnitude. Among the three neighbors considered, the one with highest gradient value is selected. A similar procedure is adopted for a vertical edge, where the connecting process starts either from upward or from downward direction. The routing process terminates when either of the two conditions is met:

(i) We move out of the edge areas.

(ii) We encounter a previously detected edge segment.

The edge map is produced in the following manner:

For each pixel p
    If p on edge
        $D_{out}(x_p) = 1$
    Else
        $D_{out}(x_p) = 0$

D_{out} is for outer edge detection (see fig 2(c)).

5.3 Inner stroke extraction with high frequency enhancement

The high frequency filter to extract inner stroke information is defined as follows:

$$I_2(p) = \min(255, I_0(p) + \Delta I_0(p))$$

where I_0 is the preprocessed gray image and I_2 is a high frequency output.
The $\Delta I_0(p)$ is defined as follows:

If $I_g(p) = 0$
    $\Delta I_0(p) = 255$
else
    $\Delta I_0(p) = (I_0(p) (255 - I_g(p))) / I_g(p)$

Where I_g is the Gaussian blur result of I_0.

The Otsu method [9] is used to separate the strokes from background. It automatically generates a threshold. Then the thresholded stroke map is produced as follows:

For each pixel p
    if $x_p > T$
        $D_{in}(x_p) = 1$
    else
        $D_{in}(x_p) = 0$

D_{in} is for inner stroke extraction (see Figure 2).

Figure 4: Original Image and Image after Inner Stroke Extraction

5.4 Stroke Integration with collaborative representation

For Stroke Integration, a collaborative representation is adopted by considering both the outer edge and inner stroke information. The detector is defined as below:

if $I_2(p)$!= 255 and $D_{out}(x_q) = 0$
    $D'(x_p) = 0$
else
    $D'(x_p) = 1$

where I_2 is inner stroke extraction fig.2(d) and q is a pixel within the eight neighborhood of p.

Further, pixel elimination is performed on: (i) Pixels in background having close grayscale values to pixels in stroke regions.These are stored in I_3 and (ii) Pixels inside stroke region but farther away from the stroke edge which are now stored in I'_2. For detail completion the two maps are combined to get the required optimal detector

$$D(x) = D_{in}(x) \ \& \ D'(x)$$

5.5 Stroke Optimization

To improve the obtained sketch, we further perform stroke optimization. This is done using the Potrace method [8]. It makes the sketch more clean and smooth by transforming the image bitmap into a vector outline.

6 WORK DONE

We initially planned to work directly on improvements and optimizations by developing on existing code, but no code for the paper was made publicly available, and the authors were unreachable over email, so we are implementing this ourselves.
We have been able to replicate most of the paper. Image pre-processing (L0 smoothing and Gaussian blur) was done as described by the authors. We have also mostly completed the implementation of the heuristic routing algorithm for outer edge detection. Apart from this, we experimented with other edge detection algorithms like Sobel[5]. We extracted the inner stroke information by the detector specifications specified by the authors. For automatic threshold computation, the Otsu [9] method was used. We also tried manual or adaptive thresholding to separate the stroke pattern from background. A collaborative representation was generated with the help of output of outer edge detection and inner stroke extraction.

It was obtained by the algorithm suggested by the authors. The images after collaborative representation and thresholding are then fused with & operator to complete the details. We also make use of Potrace method as used by authors for stroke optimization. Finally, we achieve the resultant image which is very similar to the authors' results.

The evaluation described in the paper evaluates the system by benchmarking its running time with the Canny algorithm, on a PC with defined specifications. Since this isn't a very robust quantitative evaluation, we proposed a panel-of-judges evaluation of mural2sketch. This evaluation entails a set of humans ('judges') comparing and rating groups of images (with blinded labels) outputted by mural2sketch and the benchmarking algorithm (in this case Canny).The results of the survey are then be used for quantitative analysis. We are using inter agreement metric: Cohen Kappa, Fleiss' Kappa, Scott's pi and Alpha coffecient which makes our evaluation more robust. We predict that judges mutually agreed on mural2sketch / our enhancement to it as producing more appealing outcomes than a standard edge-detection algorithm.

7 INDIVIDUAL CONTRIBUTION

Aditya Mittal- Inner stroke extraction, Thresholding, Detail Completion.

Meenakshi Maindola- Literature work, Report, Collaborative Representation.

Shiven Mian- Preprocessing, Optimization.

Shubham Gupta- Outer edge detection, Result generation, survey.

8 RESULTS

9 CONCLUSION

The paper proposes a combined line drawing generation method for ancient mural painting. It utilizes both outer edge detection and inner stroke information. With the help of the Canny detector [4], the edge anchors are obtained and connected by a heuristic routing algorithm. For inner stroke information, high frequency enhancement filter is used. The authors used running time as an evaluation metric which is not very robust. We proposed inter rated agreement based metric like Cohen Kappa, Fleiss' Kappa for better evaluation of our results.

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