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Image Processing Technology Applied To The Creation Of Bas-Relief-Like Works Of Art

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***Abstract*—Relief is an art form between round sculpture and painting. It uses compression techniques to complete another way of presenting objects in 3D space based on factors such as perspective, composition and shadows. This relief art has been widely seen in art decoration everywhere since ancient times, this shows how much it is valued and loved. This project is based on the same contour loop of the laser engraving machine, which can only have the processing characteristics of a single power and speed. Therefore, it is planned to use the image processing skills, to divide the pattern into different contour loops according to the intensity of its light and shadow. Finally, through the parameter setting of the laser engraving machine processing system, different power and speed are respectively given for processing, so that the processed parts can present different levels of depth and other relief processing effects, so that the application of laser engraving machines can be extended to other state.**

Keywords—Multi-level laser engraving, Relief art

I. Introduction

Relief art refers to a kind of sculpture that carves a raised image on a plane, and according to the thickness and style of its surface protrusions, it can be roughly divided into high relief, low relief, thin relief, intaglio carving, line carving, and hollowing out. Therefore, relief sculpture is another way of expressing sculpture art. Generally, it is attached to another plane. It is used more in architecture and can often be seen on utensils. Therefore, relief sculpture is an art form between circular engravure and painting. It has some features of circular engravure and the flatness of painting, and is as colorful as circular engravure in content, form and material. Generally speaking, high relief is closer to circular engravure in its spatial structure and shaping characteristics due to its higher and thicker origin and less compression of shape, even the local treatment is completely processed by circular engravure, it is usually placed in a high position, the visual viewing space is wide or the light is weak, and the theme is dignified and high relief is selected. The bas-relief is relative to the high relief, the body compression is larger than the high relief, and the sense of plane is stronger, bas-relief can make more use of perspective, illusion and other processing methods in painting, as well as various depiction techniques in painting, so that the structure of bas-relief figures and animals can be better on a relatively flat surface [1].

The thin relief is mainly based on lines, supplemented by surfaces, combined with lines and surfaces, 2 to 5 mm deep, thin and 3D, with sparse lining and dense, refined knife technique. Intaglio carving is usually carved on the panels of boxes, cabinets, beds and cabinets. No sketches are used, the knife is used as a substitute for the brush, the intention is to write first, and the intaglio pattern is carved with a bright knife method. Line engraving is a combination of painting and sculpture. It is produced by light and shadow, using light as a substitute for the brush, and even has some subtle ups and downs, giving people an elegant and subtle feeling. Hollow cutting is to remove the bottom plate of the so-called relief, thereby generating a negative space with various changes, and making the contours of the negative space and the positive space have a rhythm of mutual conversion. This technique used to be used on doors, windows, railings and furniture, and some can be viewed from both sides. Therefore, with the development of sculpture art, circular engravure has increasingly strengthened its relative independence. In contrast, although relief sculpture is more subject to a kind of dependence, that is, the dependence on "plane" or "wall", but Its unique expressive characteristics and rich sculptural modeling methods are still irreplaceable by other art forms. Moreover, its aesthetic characteristics have increasingly strengthened its relative independence under the promotion of the modern art revolution. The dependence and adaptability to the fixed "wall" is no longer as strong, restrained and unshakable in modern reliefs as in classical reliefs. For modern relief sculpture, the "wall" as a carrier or environment is free and optional [2].

Laser processing technology is the simplest and most common processing and manufacturing technology in today's era, and has obvious competitive advantages over traditional processing methods. Because laser processing is a non-contact processing method, it will not produce frictional resistance between the tool and the surface of the workpiece, nor will it directly impact the workpiece, and the workpiece will hardly deform. The irradiated part has almost no effect, so laser processing is a high-speed, high-efficiency and high-precision processing method. And because the laser processing technology is a combination of optical and electromechanical technology, the moving speed, power density and direction of the laser beam can be adjusted, and it is easy to cooperate with the numerical control system to process complex workpieces, which can achieve different levels and range of applications.

The laser engraving technology is a processing method in which the laser beam is focused and the material surface is directly removed to produce a dent effect based on the workpiece pattern designed in the software. Generally, it can be divided into the following three processing modes [3]:

(1) Cut engraving: the graphic information is first decomposed into countless cutting lines, and then the laser is used to cut according to these lines, and finally the graphic represented by the cutting lines is obtained.
(2) Intaglio engraving: remove the graphic part and keep the peripheral part of the pattern as it is, so the graphic part must be a closed outer outline.
(3) Relief engraving: remove the non-graphics and text parts, keep the graphic and textual parts as they are, so the graphic and textual parts must also be closed external outlines.

At present, most of the laser engraving machines can accept the "DXF" file format for the input of graphic data. The so-called DXF here is the abbreviation of AutoCAD DXF (Drawing Interchange Format or Drawing Exchange Format), which is a CAD data file format developed by Autodesk for CAD data exchange between AutoCAD and other software [4].

Therefore, this paper uses the image processing process to distinguish several different areas of the image according to the degree of light and shadow, and establishes individual contours for each area, and then outputs the individual contour curves. It is converted into several "DXF" format files, and combined with the processing parameters of the laser engraving machine such as moving speed, moving distance and power density, so that the surface of the workpiece can present the artistic creation effect similar to bas-relief with different processing depths.

II. IMAGE PROCESSING RELATED TECHNOLOGY

Image processing is simply to digitize images, so that people or computers can obtain more and more useful information from the processed digital images, and make more reliable follow-up judgments, analysis, and applications. Generally speaking, the method of digital image processing can be roughly divided into three processes: front-end, middle-stage and post-processing [8].

(1) Front-end processing: In the application of digital image processing, the front-end processing program must first be used to enhance image contrast, grayscale and noise removal to facilitate the mid-stage processing program.
(2) Mid-stage processing: The mid-stage processing process can be divided into image segmentation and representation and description. The purpose of image segmentation is to divide the digital image into several areas; for example, the binary method, equalization, area method, boundary method and edge method, etc., all use different threshold values to separate the main objects for reparation the post-processing. The representation and description are to display the important features of the image information as a basis for image quality adjustment; for example, the phase value distribution of a grayscale image can be used as a basis for the equalization of the entire image.
(3) Post-processing: how to combine applications with other fields is the category of post-processing; for example, combining neural network-like algorithms and image processing technology to identify patterns is an image post-processing processing function.

A. *Grayscale image*

Generally speaking, when we are doing image processing, we will represent each pixel in a color image as an RGB value, and each color of RGB occupies 8 bits, a total of 24 bits, so it is also called three-channel image. And a grayscale image only needs to be represented by one channel, that is, 8bit. So if we want to convert an RGB color image into grayscale, the most direct and simple way is to add the three RGB values and divide them by three to get the result we want. However, because the human eye actually has different perceptions of the brightness of the three colors, green, red, and blue. The grayscale method mostly uses the function Gray=f(R, G, B) proposed by Hasan and Karam [6] to map the color space to the gray space. Which is;

$$Gray = 0.299 * Red + 0.587 * Green + 0.114 * Blue$$

Its conversion relationship is shown in Figure 1;

(a) Original image (b) Grayscale image

Figure 1 Grayscale image picture

B. *Segmented image - binarization processing*

In order to divide the gray-scale image into different contour loops, and then give different power and speed for processing, so that the processed parts can show the processing effect of different levels and depths. In this paper, it is proposed to divide the gray value of each pixel in the gray-scale image into 5 groups according to the binarization process, and then plan different contour areas for each group according to its distribution. In this way, the setting requirements for laser engraving machine processing can be achieved.

The so-called binarization processing here is one of the simplest methods of image segmentation. Binarization can convert a grayscale image into a binary image, set the pixel grayscale greater than a certain critical grayscale value (threshold) as the grayscale maximum value, and set the pixel grayscale less than this value as gray degree minimum, so as to achieve binarization. According to the different thresholds, the binarization algorithm is divided into fixed thresholds and adaptive thresholds. At present, the commonly used binarization methods include: bimodal method, P-parameter method, iterative method and OTSU big law. In this paper, the OTSU big law is used to calculate the appropriate threshold value that minimizes the variance of the original graphics. The calculation process is as follows [7];

1. Calculate the histogram and probability for each gray value.
2. Set the initial values of $w_i(0)$ and $u_i(0)$.
3. Bring in all possible thresholds, t = 1 ..... 255.
   (a) Update the values of w_i and u_i.
   (b) Calculate the value of $\sigma_b^2(t)$.
4. Calculate the required threshold corresponding to the largest $\sigma_b^2(t)$.
5. Calculate the value of the two maxima $\sigma_{b1}^2(t)$ and $\sigma_{b2}^2(t)$, where $\sigma_{b1}^2(t)$ is the maximum and $\sigma_{b2}^2(t)$ is the greater or equal maximum.
6. The appropriate threshold is (threshhold1 + threshhold2)/2.

Figure 2 is an illustration of the result after the image is segmented by the threshold 153;

(a) Original image

(b) The image is segmented by the threshold 153

Figure 2 The result after the image is segmented by the threshold 153

C. Image difference set

As can be seen from the previous content, after the image is processed by binarization, there are only two areas of black and white, and the smaller the threshold, the larger the area covered by white. Therefore, in order to find the coverage area between two thresholds, in geometric operations, the "difference set" command can be used to remove the coverage area with a larger threshold from the coverage area with a smaller threshold, the remaining part is the area covered by the two thresholds. Figure 3 is a diagram showing the operation result of the image difference set.

(a) Threshold 102 (b) Threshold 51 (c) Threshold 102~51

Figure 3 Image difference operation result

D. Filtering to remove noise and smoothing

For subsequent processing procedures, noise removal and smoothing are usually required. However, in order to remove noise, the image contrast may be reduced, and good quality may require a lot of processing time. Therefore, a suitable method is usually selected according to actual needs. At present, there are common filtering and smoothing methods: mean filtering, box filtering, Gaussian filtering, median filtering, bilateral filtering and custom filtering. Generally speaking, filtering methods can be divided into two types, linear filtering and nonlinear filtering. Among them, linear filtering has a core with fixed parameters, and the common ones are mean filtering, box filtering and Gaussian filtering. Non-linear filtering does not have a core with fixed parameters, and common ones are median filtering, bilateral filtering and custom filtering. In this paper, Gaussian filtering is used to remove noise and smooth digital images. Gaussian smoothing filter, also known as low-pass filter, is mainly used to eliminate the high-frequency changes on the image and strengthen the low-frequency part, make the changes of the image more uniform, which can produce a blurrier image and reduce the part of the sharper image. It is usually used to reduce image noise and reduce the level of detail. Different from the mean filter and the box filter, the weight value of each pixel is the same. The mask of the Gaussian filter will strengthen the weighting value of the center point, and reduce the weighting value far from the center point [9]. For example, the mask of Gaussian filter can be shown in Table 1.

Table 1 Gaussian smoothing mask

1	2	1
2	8	2
1	2	1

From a mathematical point of view, the Gaussian blurring process of an image is the convolution product of the image and the normal distribution. Since the normal distribution is also called Gaussian distribution, this process is also called Gaussian blur. The value of each pixel is the weighted average of the surrounding adjacent pixels. The value of the original pixel has the largest Gaussian distribution value, so it has the largest weight value. The further the adjacent pixels are from the original pixel, the smaller the weight value is. If Table 1 is used as the Gaussian smoothing mask of the 3*3 convolution product to process some of the grayscale image data in Table 2, the calculation method is as follows;

Table 2 Partial grayscale image data

197	25	106	156	159
149	40	107	5	71
163	198	226	223	156
222	37	68	193	157
42	72	250	41	75

1. Calculate the sum of the elements in the mask (1+2+1+2+8+2+1+2+1=20).
2. Divide each element of the mask in Table 2 by the sum of the elements calculated in step 1. Then the mask in Table 1 becomes the mask shown in Table 3.

Table 3 New Gaussian smoothing masks

0.05	0.1	0.05
0.1	0.4	0.1
0.05	0.1	0.05

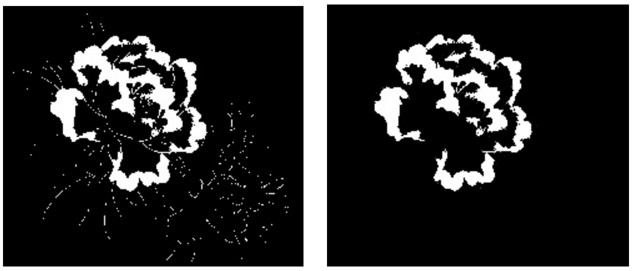
3. Recalculate part of the grayscale image data in Table 2. For example, Gaussian filtering is performed on the pixel with the pixel value of 226 in the third row and third column of Table 3. The calculation method is:

new value = (40*0.05+107*0.1+5*0.05) +
(198*0.1+226*0.4+223*0.1) +
(37*0.05+68*0.1+193*0.05)
= 163.754 = 164

Therefore, if the 5*5 filter mask is used as the benchmark, and the standard deviation of the mask in the X-axis and Y-axis directions is set to "0" to filter out the noise in the image, the execution result is shown in Figure 4. Show;

Table 4 New values of some gray-scale image data

		164		



(a) Image after threshold 204 segmentation (b) Image after Gaussian filtering

Figure 4 Comparison of the original image and Gaussian filter smoothing

E. Edge detection

After completing the filtering and smoothing of the image, the next step is to find the edge of the image and then draw the outline of the image. The three most commonly used edge detection methods are: Laplacian, Sobel and Canny, these techniques all use grayscale images, based on the difference in the grayscale of each pixel, different objects have obvious edge features at their boundaries to distinguish them. These three methods all use one-dimensional or even two-dimensional differentiation. Strictly speaking, they can be divided into two types according to their different technical principles: Laplacian was originally called the Laplacian method, which detected zero crossings of the second derivative on intensity changes, while Sobel and Canny used gradient methods, which were calculated by calculating detect changes in the first derivative of intensity of pixel luminosity for edge detection [8]. In this paper, the hybrid mode of Sobel and Canny is integrated, that is, Sobel is used to quickly calculate the gradient value of the image, and then Canny is used to complete non-maximum suppression and image edge detection, and finally complete the image contour drawing to achieve the laser engraving machine implements the requirements of the input format of scanning processing parameters. Therefore, the entire execution process of edge detection can be divided into the following steps:

Step 1: Calculate the gradient size and direction of the image – Sobel techniques

The significance of the image gradient size is the speed of image change. For the edge of the image, where the gray level value changes greatly, the gradient value is also larger. On the contrary, for the smoother part of the image, the change of the gray level value is small, and the corresponding gradient value is also small. Therefore, the calculation of the image gradient is the collection of information on the edge of the image. In this paper, the "Sobel filter" is first used to calculate the gradient value of the image. The main reason is that "Sobel filter" is a discrete differential operator, and this method combines Gaussian filtering smoothing and differential partial derivative operations, so it can process denoising filtering and finding image edges at the same time. Among them, "Sobel horizontal filter" and "Sobel vertical filter" are shown in Table 5;

Table 5 Sobel horizontal filter and vertical filter

(a)Sobel horizontal filter

-1	0	1
-2	0	2
-1	0	1

(b) Sobel vertical filter

-1	-2	-1
0	0	0
1	2	1

(a) Calculation method of the approximate value of the partial derivative in the horizontal direction

Perform the convolution product calculation of the "Sobel horizontal filter" and the original image "src", then the change of the pixel value in the horizontal direction can be obtained, that is, the value of the partial derivative G_x in the horizontal direction;

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \times src$$

Among them, src is the original image, if it is assumed that 9 pixels are as shown in the following table;

Gx =

-1	0	1
-2	0	2
-1	0	1

*

*P*1	*P*2	*P*3
*P*4	*P*5	*P*6
*P*7	*P*8	*P*9

To calculate the horizontal partial derivative $P5_x$ of the pixel point P5, the calculation formula is:

$P5x=(P3 - P1) + 2 * (P6 - P4) + (P9 - P7)$

That is, the pixel value of the left pixel point is subtracted from the pixel value of the pixel point on the right side of the pixel point P5. Among them, since the intermediate pixel points P4 and P6 are relatively close to the pixel point P5, the weight of the pixel difference value thereof is 2.

(b) Calculation method of the approximate value of the partial derivative in the vertical direction

Perform the convolution product calculation of the "Sobel vertical filter" and the original image "src", then the change of the pixel value in the vertical direction can be obtained, that is, the value of the partial derivative G_y in the vertical direction;

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \times src$$

Among them, src is the original image, if it is assumed that 9 pixels are as shown in the following table;

Gy =

-1	-2	-1
0	0	0
1	2	1

*

*P*1	*P*2	*P*3
*P*4	*P*5	*P*6
*P*7	*P*8	*P*9

To calculate the horizontal partial derivative $P5_y$ of the pixel point P5, the calculation formula is:

$P5y=(P7 - P1) + 2 * (P8 – P2) + (P9 – P3)$

That is, the pixel value of the next row of pixel points is subtracted from the pixel value of the next row of pixel points of the pixel point P5. Among them, since the intermediate pixel points P8 and P2 are relatively close to the pixel point P5, the weight of the pixel difference value thereof is 2. However, in practice, the calculated gradient value may produce negative numbers. Therefore, if the processed image is of 8bits type, all negative numbers will be automatically truncated to "0" and information will be lost. Therefore, in order to avoid this situation, we usually take the absolute value of the calculated value during calculation to ensure that the data will not be truncated. Figure 5 is a preliminary edge of the image processed by the Sobel filter.

(a) Image after Gaussian filtering (b) The image after Sobel filter processing

Figure 5 The preliminary edge of the image processed by the Sobel filter.

F. Non-maximum suppression – Canny techniques

After completing the calculations in the above steps, you can start to check the magnitude and direction of the gradient of each pixel in the image, and remove all non-edge points. In practice, it checks each pixel one by one, and determines whether the pixel is adjacent to the pixel with the same gradient direction and the maximum value, and then decides whether to remove the pixel. Therefore, this step is a process of edge thinning. For example; Table 6 is the partial area data of the image to be processed, the value in the table is the gradient size of the pixel, and the direction of the arrow is the gradient direction of the pixel.

Table 6 Gradient values of data in some regions of the image to be processed

4↑	5↑	3↑	3↑	6↑
3↑	4↑	8↑	8↑	5↗
5↑	7↑	6↑	5↑	3↑
6↑	3↑	5↑	4↗	5↑
3↑	6↑	2↑	4↑	6↑

In Table 6, the points on the black background all have their gradient directions vertically upward (ie, they can be regarded as horizontal edges). Therefore, these points are preserved and the rest are reset to "0". So these black background points will be regarded as edge points. Therefore, after the above processing, only one edge point in the same gradient direction will be retained, so the purpose of edge refinement can be achieved. However, after completing the above operations, there is still a lot of noise in the image, so in this article, a "bilateral threshold" is set to filter out inappropriate pixels. The so-called "bilateral threshold" here is to set a high threshold Val_{max} and a low threshold Val_{min}, and then according to the relationship between the gradient value of each pixel and the two thresholds, to determine the attribute of the pixel, its judgment The relationship is as follows;

(1) If the gradient value of a pixel is greater than or equal to the threshold Val_{max}, mark this pixel as a "main edge".

(2) If the gradient value of a pixel is between the thresholds Val_{max} and Val_{min}, mark the pixel as a "secondary edge".

(3) If the gradient value of the pixel point is less than or equal to the threshold value Val_{min}, then the

pixel point mark is set to "0", that is, the pixel point is removed as an edge pixel.

Then we process those pixels labeled as "minor edges". This step is mainly to deal with whether the "secondary edge" pixel is connected with the "primary edge", so the judgment principle is;

(1) If the pixel is connected to the "main edge", change the pixel to "main edge".

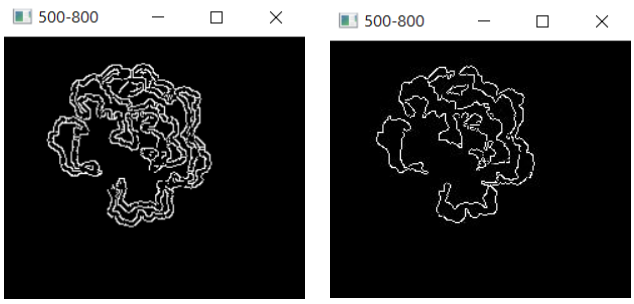
(2) If the pixel is not connected to the "main edge", remove the pixel.

Figure 6 represents of the result of processing the edge of a graph with different ranges of threshold intervals (32, 128) and (300, 500). It can be seen from the results that the size and interval of the two thresholds are related to the amount of edge data details. When the threshold is smaller, more details can be captured, but there will be more relatively useless boundary data.

(a) Threshold 32-128 (b) Threshold 300-500

Figure 6 The comparison of threshold processing between different ranges

Although edge detection can detect the edge of the image, the edge of the processed image is likely to be discontinuous and not a whole, so it cannot meet the needs of the 3D drawing software to construct 3D solid models. Therefore, in the end, it is still necessary to connect the edge and pixels of each region with different contour curve loops, as shown in Figure 7.



(a) Original image (b) The contour curve loops

Figure 7 The contour curve loops

III. DXF FORMAT FILE OUTPUT

DXF files are actually composed of pairs of characters and their associated values. These words (commonly known as group codes) are used to indicate the type of the following value. Using these group code and value pairs, DXF files can be organized into sections consisting of records. A record consists of a group code and a data item, each group code and value on its own line in the DXF file. Each section starts with group code 0 followed by the SECTION string, followed by group code 2 and a string representing the section name (for example, HEADER). Each section consists of several group codes and values that define its elements, and a section ends with a group code of 0 followed by the ENDSEC string. The overall organization of the DXF file is as follows [4]:

- HEADER section. Contains general information about the drawing. It consists of the AutoCAD database version number and some system variables. Each parameter contains a variable name and its associated value.
- LASSES section. Holds information about application-defined classes whose instances appear in the BLOCKS, ENTITIES, and OBJECTS sections of the database. Class definitions are permanently fixed in the class hierarchy.
- TABLES section. Contains definitions for the following symbol tables ; APPID (Application Identification Table), BLOCK_RECORD, DIMSTYLE, LAYER, STYLE, UCS, VIEW, VPORT.
- BLOCKS section. Contains the block definitions and drawing primitives that make up the reference of each block in the drawing.
- ENTITIES section. Contains graphical objects (elements) in drawings, including block references (insert elements).
- OBJECTS section. Contains non-graphical objects in the drawing. All objects that are not entities, symbol table records, or symbol tables are stored in this section. A dictionary containing polyline patterns and groups is an example of an item in the OBJECTS section.
- THUMBNAILIMAGE section. Contains preview image data of the drawing. This is an optional segment.

Figure 8 is a partial content of the contour curve in DXF format.

```
  0
SECTION
  2
HEADER
  9
$ACADVER
  1
AC1014
  9
$ACADMAINTVER
 70
     0
  9
$DWGCODEPAGE
  3
BIG5
  9
$INSBASE
 10
0.0
 20
0.0
 30
0.0
  9
$EXTMIN
```

Figure 8 Part of the DXF format of the contour curve

IV. SYSTEM OPERATION STEPS

As mentioned above, this paper uses the image processing process to distinguish several different areas of the image according to the degree of light and shade of the image, and establishes individual outlines for each area, then output the individual external contour curves into several "DXF" format files, and combine the processing parameters such as the moving speed, moving distance and power density of the laser engraving machine, the surface of the workpiece can present a bas-relief-like artistic creation effect with different processing depths.

Step 1: Load the original image, as shown in Figure 9.

Figure 9 Original image.

Step 2: Process the background of the original image, as shown in Figure 10.

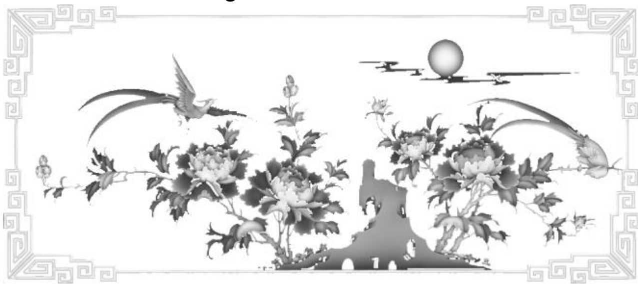


Figure 10 The original image of removing the background

Step 3: Segment the image - binarization. That is, according to the gray scale value of each area of the graph, different areas are divided. Here we plan to divide this pattern into 5 different regions according to its gray scale value. The segmentation thresholds are 200, 150, 100, 50, 0 and other 5 values. The state of the divided regions is shown in Figure 11.

(a) Regions with the threshold of 200

(b) Regions with the threshold of 150

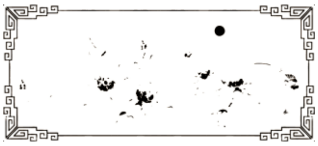
(c) Regions with the threshold of 100

(d) Regions with the threshold of 50

(e) Regions with the threshold of 0

Figure 11 Areas divided by each threshold

Step 4: Image difference processing, and find the regions between the thresholds respectively. The results are shown in Figure 12.

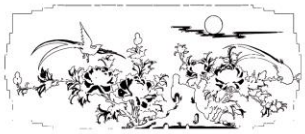


(a) Areas with a threshold of 200 or more

(b) Area between threshold 200 ~ 150

(c) Area between threshold 150 ~ 100

(d) Area between threshold 100 ~ 50



(e) Areas with a threshold of 50 or less

Figure 12 Area between thresholds

Step 5: Filtering to remove noise and smoothing. The following are all graphs with a threshold value of 100 ~ 50 as an example, and the result is shown in Figure 13.

Figure 13 Filtering to remove noise and smoothing

Step 6: Detect edges with Sobel bidirectional filter, the result is shown in Figure 14.

Figure 14 Sobel bidirectional filter edge detection results

Step 7: Suppress the non-maximum value with the Canny function, and the result is shown in Figure 15.

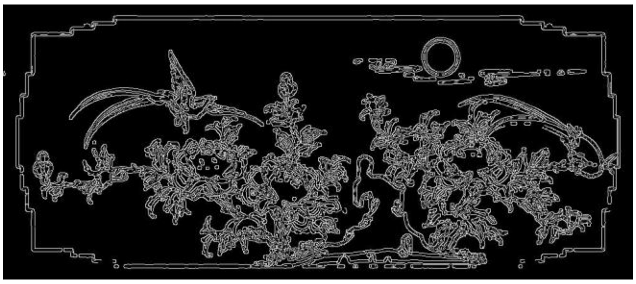


Figure 15 Illustration of Canny function suppressing non-maximum values

Step 8: Draw the contour curve, the result is shown in Figure 16.

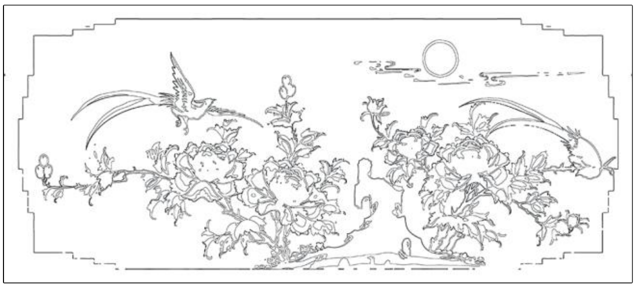
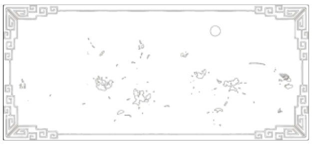
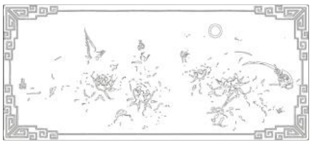


Figure 16 The contour curve of the graph in the threshold value range of 100 ~ 50

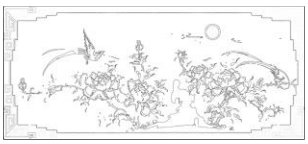
Step 9: In the same way, complete the contour curves of the regions between the thresholds in the same steps, and the results are shown in Figure 17. And Figure 18 is a combination diagram of the contour curves of each interval.



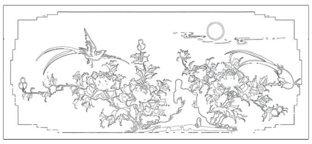
(a) Contour curves with a threshold of 200 or more



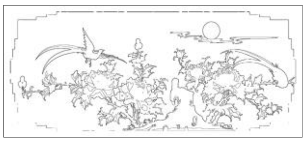
(b) Contour curves between threshold 200 ~ 150



(c) Contour curves between threshold 150 ~ 100



(d) Contour curves between threshold 100 ~ 50



(e) Contour curves with a threshold of 50 or less

Figure 17 The contour of the region between the thresholds

Figure 18 Combination diagram of contour curves of each interval

Step 10: Output the contour curves of the regions between the thresholds into corresponding DXF format files respectively. Then import it into the laser engraving system, at the same time, you can add appropriate text, and then give the appropriate processing parameters respectively to complete the processing settings like bas-relief. Figure 19 is a simulation diagram of importing into the laser processing system.

Figure 19 Simulation diagram of the laser processing system

V. CONCLUSION

This article uses a laser engraving machine to create an artistic creation with a similar bas-relief effect on a wooden board. It is different from the previous creation mode that was processed manually by artists or CNC machines. This method not only has a faster processing speed, but also retains lightning on the surface The burn marks of the laser processing machine, and this mark also causes the light and dark gradient effect of light and shadow, which is incomparable with the previous construction methods. It is planned to use the image processing skills, to divide the pattern into different contour loops according to the intensity of its light and shadow. Finally, through the parameter setting of the laser engraving machine processing system, different power and speed are respectively given for processing, so that the processed parts can present different levels of depth and other relief processing effects, so that the application of laser engraving machines can be extended to other state. Figure 20 shows the final product after processing.

Figure 20 The final product after processing

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