Research on Splicing Technology of Large Format Three Dimensional Printing

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Abstract. With the development and maturity of 3D printing technology, there are new requirements for printing accuracy, clarity, and frame size. This article mainly focuses on large-format printing technology, using projection splicing technology to realize large-format digital light processing projection splicing 3D printing technology. Aiming at the problem of projection distortion, the article implements multiple digital light processing projection distortion correction; Aiming at the problem of image stitching, the article uses secondary Alpha edge fusion to realize image stitching, and gives an experimental environment to compare the results. According to the above steps, combined with actual pictures, a good splicing effect is achieved.

1. Introduction

Digital light processing (DLP) 3D printing technology is a digital light source in the form of surface light to project layer by layer on the surface of liquid photosensitive resin, and layer by layer is cured. German Envisiontec and domestic Luen Thai technology companies mainly use digital light processing (DLP) imaging to achieve printing technology. According to data query and comparison, DLP imaging technology is limited by the number of pixels of the display device, between the print size and accuracy requirements There are mutual constraints, and it is difficult to achieve high precision and large size at the same time with a single DLP [1-2]. If multiple DLP projection splicing can be realized, it will increase the possibility for the realization of large-format 3D printing technology. Therefore, this paper proposes a method of large-format stitching of multiple DLPs to improve the shortcomings of current 3D printing.

For image stitching, two problems need to be solved. One is image distortion correction, which can be corrected by manual or automatic adjustment of equipment, and the other is image fusion. Under the premise that the distortion is adjusted, the image is edged. Fusion, adjust its definition uniformity and brightness to ensure that the image is not distorted. Alpha channel fusion [3] can be used to process the overlapped part after distortion registration to obtain a spliced image. Therefore, this paper applies projection stitching technology to 3D printing DLP projection stitching to realize multiple DLP 3D printing technology.

2. System Components

The splicing system consists of a servo motor, 2 DLP optical engines, a projection platform and a plate camera. The servo motor is used to adjust the definition up and down. The general term of the optical machine composed of two DLP optical machines is used to project on the debugging optical machine.
screen, and the projected image fusion algorithm is fused, debugged and optimized, so that the two screens are seamlessly connected [4]. Using a plate camera to analyze and verify the acquired images, analyze the images acquired by stitching, calculate the brightness of each pixel, and obtain the contrast, which provides a certain degree of reliability for the brightness problem in the subsequent edge fusion. As shown in Figure 1.

![Figure 1. Schematic diagram of calculating brightness.](image1)

![Figure 2. Schematic diagram of calculating the brightness of the overlapping area.](image2)

In the seamless splicing of multi-channel projections, after geometric correction and color correction are completed, the projected images in the overlapping area come from two projectors, showing an optical bright band, as shown in Figure 2. The highlighted part of the stitched image in the overlapping area greatly affects the stitching effect. The Alpha edge fusion method can effectively solve the brightness difference in the overlapping area, as shown in Figure 3 Shuangpin stitching flowchart.

![Shuangpin splicing flowchart](image3)

**3. Distortion correction**

Before fusion splicing, the effectiveness of equipment and image preprocessing determines the degree of fusion effect. Therefore, image preprocessing is required. Distortion correction is the distortion of the image during the projection exposure process, which can be divided into distortion caused by the optical system and distortion caused by the mechanical structure.

When the projector is not aligned vertically with the projection plane, the projected image will be distorted in the horizontal or vertical direction, that is, trapezoidal distortion. The overall outline of the projected picture presented is an irregular quadrilateral rather than a standard rectangle.

In addition to the distortion caused by the mechanical structure, there is also distortion caused by the optical system. The degree and type of geometric distortion caused by the optical system of different projectors to the projected image are slightly different, mainly divided into: radial distortion and tangential distortion. The imaging process of the camera is essentially the conversion of the coordinate system. First, the points in the space are converted from the "world coordinate system" to the "camera coordinate system", and then they are projected onto the imaging plane (image physical coordinate system), and finally The data on the imaging plane is converted to the image pixel
coordinate system. Therefore, for radial distortion, the main idea of coordinate mapping can be adopted to correct the image.

Radial distortion correction formula:

\[ x_{\text{corr}} = x_{\text{dis}}(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) \]  
\[ y_{\text{corr}} = y_{\text{dis}}(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) \]  

Among them, \( x_{\text{dis}}, y_{\text{dis}} \) indicate the coordinate with distortion, \( x_{\text{corr}}, y_{\text{corr}} \) indicate the coordinate after repair, \( k_1, k_2, k_3 \) indicate the radial distortion parameter, and \( r \) is related to the camera's radial direction Value.

Tangential distortion correction formula:

\[ x_{\text{corr}} = x_{\text{dis}} + [2p_1 xy + p_2 (r^2 + 2x^2)] \]  
\[ y_{\text{corr}} = y_{\text{dis}} + [2p_2 xy + p_1 (r^2 + 2y^2)] \]  

Among them, \( x_{\text{dis}}, y_{\text{dis}} \) represent the coordinate with distortion, \( x_{\text{corr}}, y_{\text{corr}} \) represent the coordinate after repair, \( p_1, p_2 \) represent the tangential distortion coefficient, and \( y \) is the value related to the pixel position.

Therefore, five parameters about distortion can be obtained:

\[ D = (k_1, k_2, k_3, p_1, p_2) \]  

In the coordinate conversion and processing, the image coordinates are not necessarily integers, so it is necessary to fit the numbers. This article uses the least squares method for polynomial fitting:

Let the distorted image be \( f = (x, y) \) and the corrected image be \( g = (u, v) \). The relationship between a point \((x, y)\) in the distorted image and a point \((u, v)\) in the corrected image is:

\[ \begin{align*}
  u &= \sum_{i=0}^{N} \sum_{j=0}^{N} a_{ij} x^i y^j \\
  v &= \sum_{i=0}^{N} \sum_{j=0}^{N} b_{ij} x^i y^j
\end{align*} \]  

Where \( a_{ij} \) and \( b_{ij} \) are polynomial coefficients, and \( N \) is the degree of polynomial.

Least squares method:

\[ \varepsilon_x = \sum_{l=0}^{L} \left( u_l - \sum_{i=0}^{N} \sum_{j=0}^{N-i} a_{ij} x_l^i y_l^j \right)^2 \]  
\[ \varepsilon_y = \sum_{l=0}^{L} \left( v_l - \sum_{i=0}^{N} \sum_{j=0}^{N-i} b_{ij} x_l^i y_l^j \right)^2 \]  

Among them, \( L \) is the number of control points, which can be verified by the program. In order to further observe the state of the correction process, the image grid is adopted, and a DLP projection light machine projects 4×4 grids, and the result can be seen directly. The following figures 4 and 5 give a comparison chart before and after correction.

4. Alpha channel edge blending

The Alpha channel uses the gray-scale method to record the transparency of the image, this feature can play a very good effect in the image fusion processing. In the seamless splicing of multiple projectors, the feature of Alpha channel is used to realize seamless splicing.

In a multi-projection splicing display system, after geometric correction is completed, the image displayed on the projection screen is no longer deformed, and the adjacent channel images have been
aligned, but the brightness of the overlapped area is changed, resulting in a bright band. As shown in Figure 6. In order to achieve better edge fusion, you need to use Alpha fusion to do edge processing on the overlapped area.

![Figure 6. Schematic diagram of projection fusion](image)

In the experiment, a complete image is selected and divided into two parts, and a DLP projection is used for one part of the image. Extend the left projection image to the right by pixels, and the right projection image to the left by the same amount of pixels. At this time, the brightness of the image changes, as shown in Figure 7(a). After stitching, the brightness of the overlapping part is uneven, as shown in Figure 7(b), the plate camera is used to collect and analyze the brightness of the image, and then the edge fusion algorithm is used to change the brightness attenuation, and the middle part of the image is processed in a gradual manner, such as Figure 7 (c), the final stitched image is obtained.

![Figure 7. Dual screen splicing](image)

4.1. Fusion function

The processing of edge blending requires a good edge blending function. If the edge fusion function is not properly selected, the ideal edge fusion effect will not be achieved. As shown in formula 9.

\[
    f(x) = \begin{cases} 
        a(2x)^p & x \in [0,0.5] \\
        (1 - (1 - a)[2(1 - x)])^p & x \in [0.5,1] 
    \end{cases}
\]  

(9)

Where: \( x \) is the relative position of the pixel column in the superimposed area, and \( p \) is the influence factor, which is used to adjust the degree of curvature of the edge fusion function. \( a \) is the brightness adjustment coefficient. According to the empirical value, 0.5 is the dividing line. When \( a>0.5 \), the center of the processed superimposed area will be brighter than other areas. When \( a<0.5 \), the center of the processed superimposed area will be darker than the surrounding area. Therefore, this paper selects the edge fusion function when \( a=0.5 \) to overlap. Area image processing. The edge fusion function curve when \( a=0.5 \) is shown in Figure 8.

The curvature of the curve depends on the parameter \( p \). When \( p=1 \), the curve is linear, which means that the transparency Alpha changes uniformly in a straight line. When \( P=1 \), the fusion function is in the form of a straight line. When \( P=2 \), the fusion function is in the form of a second-order curve, when \( P=3 \), the fusion function is in the form of a third-order curve.
4.2. Linear fusion

This paper analyzes and tests the linear fusion function of P=1 and the conic fusion of P=2. Experiments show that in linear fusion, for linear attenuation, the following left-projection attenuation formula is obtained:

\[
    f_L(x) = \begin{cases} 
    0.5(2x) & x \in [0, 0.5] \\
    1 - (1 - 0.5)[2(1 - x)] & x \in [0.5, 1] 
    \end{cases} \tag{10}
\]

Then the right projection attenuation formula is:

\[
    f_R(x) = 1 - f_L(x) \tag{11}
\]

As shown in Figure 9 and 10: a schematic diagram of the left and right projection attenuation curve is given:

At this time, the Alpha attenuation effect of the fusion zone is shown in Figure 11. It can be clearly seen from the figure that the brightness steps of the fusion zone and the non-fusion zone are more obvious, the transition is not smooth, and a "black line" is formed at the junction. The simple linear attenuation of the image fusion is still not ideal. Although the brightness of the fusion zone is reduced, it also brings new problems. The fusion zone becomes darker, and there is a clear "black" at the junction with the non-fusion zone line."
4.3. Secondary fusion image

Based on the theoretical analysis of the above fusion curve, the image is fused in the form of a quadratic fusion curve, and the expression for the left projection is:

\[
\begin{align*}
    f_L(x) &= \begin{cases} 
        0.5(2x)^2 & x \in [0, 0.5] \\
        1 - (1 - 0.5)[2(1 - x)]^2 & x \in [0.5, 1] 
    \end{cases}
\]

Then the right projection attenuation formula is:

\[
    f_R(x) = 1 - f_L(x)
\]

As shown in Figure 12 and 13, the left and right attenuation curves are given:

At this time, the attenuation effect of Alpha is shown in Figure 14. The fusion zone and the non-fusion zone no longer have obvious boundaries, the brightness transition is natural, and the brightness change is also very soft and uniform. Compared with the linear attenuation effect, it can better meet the needs of seamless splicing of multiple projectors.

5. Conclusion

Set up a DLP projection splicing environment in the laboratory to correct the two DLP projections, mainly to adjust the distortion caused by the optical system, use the grid to correct the generated distortion, and achieve good results, and then perform the actual image Alpha channel fusion splicing, using actual pictures for verification, meets the expected results, can realize large-format splicing technology, and assist the development of subsequent 3D printing technology.
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