Edge Fusion Algorithm for Orthogonal Projection of Multiple Overlapping Regions

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Abstract. Stereo projection display technology has become a hot topic in recent years. A edge fusion technology for multiple projection images with multiple overlapping areas is proposed. An edge fusion method is proposed, which can be used for edge fusion of multiple overlapping areas in irregular fusion areas, eliminate the bright band caused by overlapping projection and realize multi-channel seamless Mosaic display. The practical application shows that this method can make the multi-projector display system with multiple planar and different shape and multiple overlapping areas project a seamless vision.

Introduction

In order to display super-large, panoramic and three-dimensional images and realize seamless splicing of multi-channel projection system[1-2], two problems must be solved: one is to carry out geometric correction of projected images[3], and the other is to fuse the edges of adjacent images[4].

In this paper, a new edge fusion method is proposed to adapt stereo images in real scenes[5]. This edge fusion method maximizes the effective pixels of all projectors, and can support the Mosaic and display of multi-planar, irregular images and multi-overlapping multi-projector images.

Edge Fusion Algorithm for Orthogonal Projection

The geometric correction step completes the correction of the image distortion and obtains the image without geometric distortion. The whole image is segmented into a stereoscopic projection of the left side, the front side and the right side. Adjacent projection planes with overlapping areas are called fusion zones. The pixels with overlapping parts of the fusion in the stereo projection have been aligned. However, as the number of pixels in the fusion zone increases to twice the previous level, the brightness of the fusion zone is higher than that of other regions, so an obvious bright band appears in the fusion zone, as shown in figure 1. In order to keep the brightness of the fusion zone consistent with that of other regions, edge fusion processing is needed for the fusion zone.

Figure 1. Effect diagram of edge - free fusion processing.

Edge fusion is a technique that adjusts the brightness of the fusion zone to match the brightness of other regions. We can see from the renderings without edge fusion processing in figure 1 that the
brightness difference between the fusion zone region and non-other regions is obvious, and it can be seen that edge fusion has a great impact on the three-dimensional projection Mosaic.

**Edge Fusion Algorithm for Orthogonal Projection**

Edge fusion algorithm is to multiply the RGB value of each pixel in the fusion band by an attenuation function. The effect of the same plane projection without edge fusion processing is shown in figure 2 (a), and the projection edge has obvious bright band. The parameter setting in figure 2 (b) assumes that two projected images A and B are spliced to form a fusion band, in which the length of the region removing the fusion band in figure A and B are $C_A$ and $C_B$ respectively, and the length of the fusion band is $L_A + L_B$.

![Image 2](image2.png)

**Figure 2.** Same plane projection without fusion processing effect and parameter setting.

Therefore, the fusion function of the same plane is:

\[
\text{bright}_A = a \left( \frac{x}{L_A + L_B} \right) f(C_A + x) \quad (1)
\]

\[
\text{bright}_B = \left[ 1 - a \left( \frac{x}{L_A + L_B} \right) \right] f(x) \quad (2)
\]

Bright A and bright B are the brightness of projection A and B in the fusion zone, respectively. $a(x)$ is the attenuation function, and $f(x)$ refers to the RGB value of the image. The overall brightness of the fusion belt is the sum of bright A and bright B, with a constant brightness value of 1.

Since the fusion function of the same plane can only solve the situation that two projectors are playing in the same plane, it cannot solve the situation that the projectors are playing in different planes. In the fusion of different plane projections, it is difficult for the projector to completely cover a certain section of the other side, most of which will appear as shown in figure 4, forming a bright band in the hexagonal region.

![Image 4](image4.png)

**Figure 4.** Orthogonal projection without fusion effect.

Therefore, this paper proposes a fusion function for right-angle surface fusion. Suppose two projection images A and B are spliced together to form a fusion band, where the length of the region of the fusion band removed in figure A and figure B are $C_A$ and $C_B$ respectively, and the length of the fusion band is $L_A + L_B$. $P_A$ and $P_A^\perp$ is B projector in A on the surface of the boundary Angle, $P_B$ and $P_B^\perp$ is A projector in B on the surface of the boundary Angle, $P_C$ and $P_C^\perp$.
respectively is A and B point up and down below. Since the projection is an irregular hexagon on different planes, in order to facilitate the calculation of the fusion function, we need to transform it into a regular rectangle by geometric correction, as shown in figure 5.

![Figure 5. Schematic diagram for setting parameters of right-angle projection.](image)

The calculation method of the fusion function of image A and image B is shown in (3) and (4).

\[
\text{brightA} = \begin{cases} 
    a \left( \frac{x}{L_A + L_B} \right) f(C_A + x) & y \in (f_{\hat{A}C}(x), f_{AC}(x)), x \in (0, L_B) \\
    a \left( \frac{x}{L_A + L_B} \right) f(C_A + x) & x \in (L_B, L_A + L_B) \\
    f(C_A + x) & \text{others}
\end{cases}
\] (3)

\[
\text{brightB} = \begin{cases} 
    \left[ 1 - a \left( \frac{x}{L_A + L_B} \right) \right] f(x) & x \in (0, L_B) \\
    \left[ 1 - a \left( \frac{x}{L_A + L_B} \right) \right] f(x) & y \in (f_{\hat{B}C}(x), f_{CB}(x)), x \in (L_B, L_A + L_B) \\
    f(x) & \text{others}
\end{cases}
\] (4)

BrightA and brightB are the brightness of projection A and B in the fusion zone, respectively. \(f_{AC}(x)\) is the linear equation of \(P_A\) and \(P_C\): \(f_{AC}(x) = k_{AC}x + b_{AC}\). \(f_{BC}(x)\) is the linear equation of \(P_B\) and \(P_C\): \(f_{BC}(x) = k_{BC}x + b_{BC}\). \(f_{\hat{A}C}(x)\) is the linear equation of \(P_{\hat{A}}\) and \(P_{\hat{C}}\): \(f_{\hat{A}C}(x) = k_{\hat{A}C}x + b_{\hat{A}C}\). \(f_{\hat{B}C}(x)\) is the linear equation of \(P_{\hat{B}}\) and \(P_{\hat{C}}\): \(f_{\hat{B}C}(x) = k_{\hat{B}C}x + b_{\hat{B}C}\).

Each linear equation is obtained from the coordinates of the corresponding two points. For example, the equation \(f_{AC}(x) = k_{AC}x + b_{AC}\) is obtained from the linear equation constructed by the two points \(P_A\) and \(P_C\).

### Mixed Attenuation Function

In this paper, a mixed attenuation function is proposed to solve the attenuation problem in the fusion band. The mixed attenuation function uses the combination of exponential attenuation function and triangular attenuation function. In paper [6], an exponential attenuation function is proposed to solve the attenuation problem of the fusion band brightness, as shown in formula (5).

\[
\begin{align*}
    a_R(x) &= \alpha x^p & 0 \leq x \leq 1 \\
    a_L(x) &= 1 - \alpha x^p & 0 \leq x \leq 1
\end{align*}
\] (5)

Although the exponential decay function solves the black line problem and makes the brightness of the fusion zone change uniformly, the gradient from the non-fusion zone to the fusion zone is obvious and not smooth enough. As shown in figure 6, the decay of the exponential decay function is still not slow enough when it is close to the brightness 1, so there will be a phenomenon that the boundary of the fusion zone is obvious.
The trigonometric attenuation function uses the mathematical property of the trigonometric function $\sin^2 x + \cos^2 x = 1$ to attenuate the basic point\cite{7}, as shown in formula 6.

$$a_R(x) = \beta \sin^2 \left( \frac{\pi}{2} x \right) \quad 0 \leq x \leq 1$$
$$a_L(x) = \beta \cos^2 \left( \frac{\pi}{2} x \right) \quad 0 \leq x \leq 1$$

(6)

The triangular attenuation function has a significant improvement in the transition between the fusion zone and the non-fusion zone, but the brightness of the region in the middle of the fusion zone decayed so rapidly that there is a dark zone, and the dark zone gets darker and darker as the pixel gets closer to the center zone.

Appears in order to solve the above of the fusion zone regional to merge with the brightness of the inconsistent problem, the proposed hybrid damping function, adopts the exponential decay function and triangle combination of attenuation function, as described in formula 7, when x close to 1 triangle attenuation function of proportion bigger, close to zero exponential decay function accounted for a larger proportion.

$$a_R(x) = (1 - mx)^n \alpha x^p + (mx)^n \beta \sin^q \left( \frac{\pi}{2} x \right) \quad 0 \leq x \leq 1$$
$$a_L(x) = (mx)^n (1 - \alpha x^p) + (1 - mx)^n \beta \cos^q \left( \frac{\pi}{2} x \right) \quad 0 \leq x \leq 1$$

(7)

**Experimental Results and Analysis**

The effect of exponential decay function is shown in figure 7 (a). After repeated experiments, it can be known that the best effect is achieved when $\alpha = 0.9$ and $p = 0.8$. The effect of triangular attenuation function is shown in figure 7 (b). After repeated experiments, it can be known that the effect is best when $\beta = 1$.

(a)                                   (b)

Figure 7. Effect of exponential decay function and triangular attenuation function.

The mixed attenuation function effect is shown in figure 8. The experiment shows that the best effect is achieved when $m = 1$, $n = 0.83$, $p = 0.8$, $q = 1.3$, $\alpha = 0.9$ and $\beta = 1$. 88
It can be seen that the mixed attenuation function proposed in this paper can combine the advantages of exponential attenuation function and triangular attenuation function, and improve their disadvantages in different areas.

The mixed attenuation function combines the advantages of uniform brightness in the fused zone in the exponential attenuation function and the advantages of natural transition between the fused zone and the non-fused zone in the triangular attenuation function. In addition, it can solve the problem that the transition from the non-fused zone of exponential decay function to the fused zone in figure 7 is not smooth enough, and the brightness of the region in the middle of triangle decay function fusion zone in figure 8 is attenuated so rapidly that there is a dark belt and the dark belt gets darker and darker as the pixel point approaches the center.

Conclusion

Multi-plane projection display provides high resolution and seamless super large picture through the Mosaic display of multiple projectors. Aiming at the problem of projection Mosaic display of different planes, this paper proposes a method for the fusion area in different planes. In the multi-plane projection display system, this method can effectively fuse the edges of different projections without affecting the previous geometric correction steps, thus improving the image quality and viewability.

References


