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A New Keystone Correction Algorithm Based on Edge-directed Interpolation of The Projector

Yuan Ye

School of Business Information, Shanghai University of International Business and Economics
Shanghai, China
aaaayuanye@126.com

Abstract

A trapezoid is generated in screen when the projector is not perpendicular to the screen body in most situations. It is called the keystone distortion. In order to solve the keystone distortion of images, a new algorithm transforming pixel spatial position using edge preserving interpolation is proposed to implement projector keystone correction. First, the scaling factors, the start point positions and the end point positions are calculated according to different rows, then the edge preserving interpolation algorithm are used according to the space positions. Experimental results demonstrate that the algorithm can not only implement keystone correction, but also preserves the edge effectively. This algorithm can be used in the chip of projector video processing to solve the keystone distortion.

Keywords: *projector; keystone correction; interpolation algorithm; edge preserving*

1. Introduction

In the process of using the projector, in order to make the projected image on the screen be rectangle, the position of the projector needs to be perpendicular to the big screen to ensure the projected results are rectangle, as shown in Figure 1 (a). However, in most normal circumstances, the projector is not perpendicular to the screen body, but at an angle, as shown in Figure 1 (b), so a trapezoid is generated in screen. It is called the keystone phenomenon. This is caused by attempting to project an image onto a surface at an angle. It is a distortion of the image dimensions, making it look like a trapezoid, the shape of an architectural keystone. In order to make the projection in the projector screen rectangular, it can be implemented by keystone correction algorithm. There are usually two methods in trapezoid correction: optical trapezoid correction and digital trapezoid correction. Optical trapezoid correction is to achieve the purpose of trapezoid correction by adjusting the lens through physical location, while digital trapezoid correction is to adjust and compensate original image by interpolation algorithms to eliminate trapezoid distortion of the projected image. For trapezoidal distortion, digital trapezoid correction can be divided into vertical and horizontal trapezoid correction. Here only digital vertical keystone correction algorithm was studied, the horizontal trapezoid correction can be achieved similarly.

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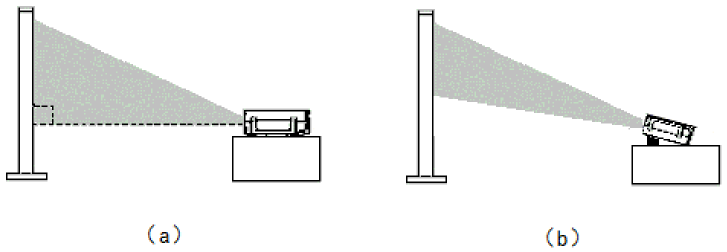


(a)Projector is perpendicular to the screen

(b) Projector is not perpendicular to the screen

Figure 1. Projector Position Illustration

There are many methods can be used to implement the nonlinear scaler of variable scale factors [1-3]. The commonly used digital trapezoid correction algorithm can be solved if image accuracy is not required [4-5]. But if those applications requires high precision image, the image projected appears burr and not smooth in some pictures edges, it is not particularly desirable. So aiming at the problems that current definition projector trapezoid correction function is not good, we propose a novel algorithm based on the edge preserving to keep trapezoid correction implementations in this paper, it can be used in projector chips. Firstly, the point of the image to be processed is transformed in space coordinate. Secondly, the scaling factor, the starting point and the end point of every row are obtained. Thirdly, relevant direction of the interpolation is obtained, and finally the relevant four neighborhood points are found with the corresponding interpolation direction. Experimental results show that the algorithm can achieve good results on the edge of the trapezoid and eliminates image blur and jagged edge effect, and it can be applied to video processing chip.

The principle of digital trapezoid correction is to produce an inverted trapezoidal compensation image to cover the problem of projected image trapezoidal distortion produced by the optical path. The source image is geometric transformed using the interpolation algorithm.

2. Isosceles Trapezoid Correction based on Edge Smooth

2.1 The Space Positions Computation

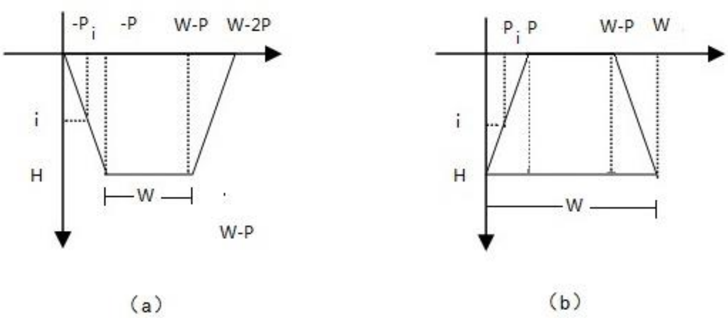
When the source image is a regular rectangular and the projector image is trapezoidal, the original image can be linearly stretched in the horizontal direction. Scaling factor of each pixel in the same row is the same, but the scaling factor in different row is different, the scaling factor has a linear relationship with the number of rows. Starting point S and end point of each line E are not the same in every row. Spatial position of the interpolation point can be obtained as follows, first starting point S and end point E of each line and the scale factor will be calculated, then the vertical coordinate of this point will be obtained:

$$
\begin{array}{l}
\mathrm{for}(i = 1 : H) \\
\{ \\
\quad x = floor(i * \frac{Height}{H} + 1) \\
\quad \Delta x = i * \frac{Height}{H} - x + 1; \\
\quad P_i = \mathrm{floor}(P * (H - i + 1)/H) \\
\quad \mathrm{if}\ (P < 0) \\
\qquad S = P_i + 1 - P; \\
\qquad E = W - P_i - P; \\
\qquad \mathrm{scale} = \mathrm{Width}/(W - 2P_i) \\
\quad \mathrm{else} \\
\qquad S = P_i + 1; \\
\qquad E = W - P_i; \\
\qquad \mathrm{scale} = \mathrm{Width}/(W - 2P_i) \\
\quad \mathrm{end} \\
\}
\end{array}
\tag{1}
$$

Wherein, H and W are the height and the width of external rectangle of the isosceles trapezoid. $Height$, $Width$ is the height and width of the source image rectangle before scaling. Where P is the half of the difference between the upper edge and the lower edge in this isosceles trapezoid. P<0 indicates that the upper edge is bigger than the lower edge of the trapezoid ,just like Figure 2 (a) shown; P>0 indicates that the upper edge is smaller than the lower edge of the trapezoid ,just like Figure 2 (b) shown; P_i indicates the distance between the first point of the ith row and the first point of the longest edge in the horizontal coordinate, it is an intermediate variable; i is the ith row of new image after scaling, x is the vertical coordinate of source image point before scaling corresponding to interpolated pixel; As shown in Figure 3, the gray points is the point to be interpolated, Δx is the vertical distance of that point to the nearest horizontal line connected two upper points. S is starting point horizontal coordinate of the i*th* row, E is ending point horizontal coordinate of the i*th* row, scale is the scaling factor of the i*th* row, Floor(.) is on behalf of rounding down operations.

The position of horizontal can be obtained as follows:

$$
\begin{array}{l}
\mathrm{for}(j = S : E) \\
\quad y\_f = \mathrm{scale} * (j - S + 1); \\
\quad y = \mathrm{floor}(y\_f) + 1; \\
\quad \Delta y = y\_f - y + 1; \\
\mathrm{end}
\end{array}
\tag{2}
$$



(a) the upper edge is bigger than the lower edge of the trapezoid(P<0)

(b) the upper edge is smaller than the lower edge of the trapezoid (P>0)

Figure 2. Isosceles Trapezoid Coordinate Illustration

Wherein, j is the j*th* column of the scaled image , y is the new horizontal position of the pixel corresponding to that point in the image before scaling; As shown in Figure 3, Δy is the horizontal distance of that point in the source image to the nearest left connection line ; y_f is intermediate variable, which is a floating value.

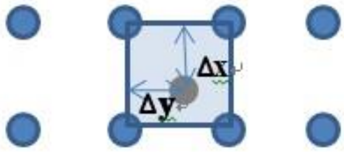


Figure 3. The Interpolation Point Position Illustration

2.2 Interpolation Algorithm

Image interpolation algorithm is the core algorithm of image geometric computing. Nearest-neighbor interpolation, bilinear interpolation and bi-cubic interpolation method algorithm are commonly used. Nearest-neighbor interpolation method can be implemented easily and processed fast, but it's just a simple copy of the original pixel to its neighborhood. There will be significantly mosaic or aliasing if the image is enlarged; The images using bilinear interpolation is smoother and the algorithm implementation is relatively simple; Using bi-cubic interpolation algorithm better results can be obtained, but algorithm implementation is complicated. Considering the complexity of hardware implementation and the effect, in general bilinear interpolation will be used.

However, if the edge direction is not considered, the interpolated image details will be blurred at the edges, it will affect the quality of the interpolated image. To make the edges of the interpolated image sharper. Many researchers proposed interpolation algorithm based on edge direction [6-10]. In general, the more sophisticated the methods are, the better results the amplification will achieve. But due to these good algorithms need to use multi-line buffer, it is not suitable for the low cost on-chip video projector.

In order to eliminate blur and preserve edges using fewer line buffers, we use the interpolation algorithm proposed in this paper [11] to maintain the edge of the image. The Step is: First, find a representative point of the insertion point, and then determine the relevant direction of the representative point. Second, find neighborhood points depending on the direction of the representative point, and then re-calculate these points in the neighborhood of the corresponding position in the direction of the new coordinates. Finally, the value of the point in the new position is obtained along the edge direction using the bilinear interpolation.

3. Simulation Results and Analysis

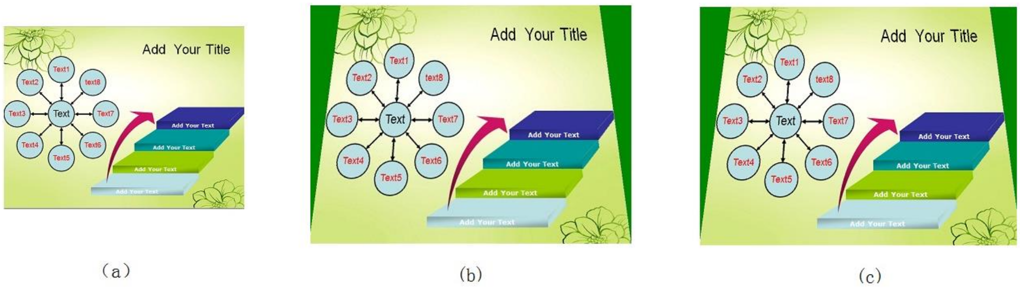
This algorithm is designed using Verilog language, the series type of FPGA (Field Programmable Gate Array) chip platform is Virtex-5, a simulation test is implemented. Figure 4 are system simulation results. Because the home projector is often used as a home theater now, a video test disc was chosen to examine projector image effect. Figure 4(a) is the original image, its image resolution is 720 ×480. Figure 4(b) and Figure 4 (c) are enlarged image using the algorithm proposed here, their image resolution are 1080×768 respectively. Figure 4(b) is compensated isosceles trapezoid image, where P = 180, its lower edge is bigger than upper edge.

Figure 4(c) is compensated isosceles trapezoid image, where P = -180,its lower edge is smaller than upper edge. Using this algorithm, the projection in the screen will be rectangle by image compensation.

(a) source image (b) p=180,using algorithm in this paper (c) p=-180,using algorithm in

Figure 4. Simulation Results Images

Considering that the projector is often used to show PowerPoint, a PowerPoint image was selected to test, the original image resolution is 600 ×450 (Figure 5 (a)), the enlarged image resolution is 800×600. Figure 5 (b) is the result using the bilinear interpolation algorithm, where, P = 80; Figure 5 (c) is the result using the edge based algorithm proposed here. Where, P = 80. Compare the image effect of (c) with (b), it can be seen that the image edges in (b) is significant jagged, the edge information of the original image can't be kept well, but the image edges in (c) can eliminate blur, keep the edge direction. The experimental results show that the edge remain enlarge algorithm proposed in this paper has good experimental results.



(a) source image (b) bilinear interpolation (c) algorithm in this paper

Figure 5. Simulation Results Images

4. Conclusion

In order to solve the keystone distortion of projectors, the keystone correction implementation algorithm is presented to keep the edges in this paper. By calculating different scaling factors, different starting points and end points of different rows, the point position in space coordinate was recalculated. Then edge-based interpolation algorithm is adopted. Simulation results show that the algorithm can implement the keystone correction of the projector image, and maintain the edge effectively .The algorithm can be applied to video post image processing chips of the projector.

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Author

Yuan Ye, PHD of shanghai Jiao Tong university, associate professor of school of business information management in shanghai university of international business and economics. The direction of research: computer vision and image processing.

