

Keystone Error Correction Method in Camera-Projector System to Correct the Projected Image on planar surface and tilted projector

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Abstract— Projector camera systems are basically systems that can serve as improvement to projector based applications by addition of visual feedback to the projector. However, unless the projector is precisely aligned to the presentation screen, the resulting image suffers from perspective (keystone) distortions requiring manual optical or digital correction. This process is manually hard during continuous movement of projector and screen of projection. Misalignment of projector and projected surface cause projective transform which change the shape of image. This paper propose a method to find largest area rectangle inside any quadrilateral. An uncalibrated, low-resolution digital camera is used to infer the projector-screen geometry and to automatically determine the parameters.

Keywords- Homography, Keystoneing, Prewrapping, Projective Transform.

I. INTRODUCTION

Projection systems have become the ubiquitous infrastructure for presentation technology. However, unless the projector is precisely aligned to the presentation screen, the resulting image suffers from perspective (keystone) distortions requiring manual optical or digital correction. This tedious process must be repeated whenever the projector or screen is moved and is increasingly relevant given the emerging trend towards highly-portable LCD projection systems. This paper presents a presentation interface that pre-warps the image to be projected in such a way that the distortions induced by the projector-screen geometry precisely negate the warping. An uncalibrated, low-resolution digital camera is used to infer the projector-screen geometry and to automatically determine the pre-warping parameters[6]. This vision-based system is augmented with a natural interface that enables the user to interactively refine the suggested rectification. Arbitrary distortions due to projector placement are negated allowing the projector (and camera) to be placed anywhere in the presentation room—for instance, at the side rather than the center of the room. Our solution works with existing projector hardware but it could easily be incorporated into the next generation of LCD projector systems. This interface has been integrated into a complete camera-assisted presentation tool since December 1999, and has received very favorable feedback[3].

II. PROJECTIVE TRANSFORM

Whenever we take any picture of square or circle from some angle we can easily judge that the shape has not remained the same as that of square or circle[10]. Distance, angle, ratio of distance or hardly any geometry is preserved by projective transformation.

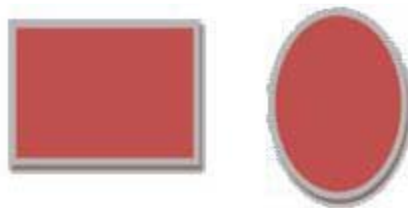


Fig 1(a). Original image

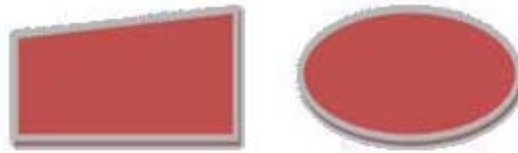


Fig 1(b). Projective transformed image

The property that is preserved by projective transform is that of 'straightness'. The projective matrix has got 8 degrees of freedom corresponding to its 8 nonunitary elements[8]. A planar projective transformation is a linear transformation on homogeneous 3-vectors represented by a non-singular 3x3 matrix.

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} & H_{13} \\ H_{21} & H_{22} & H_{23} \\ H_{31} & H_{32} & 1 \end{bmatrix} \quad (1)$$

or more briefly $x = H * x'$. H is also called as homography matrix. Each of the different transformations we have examined thus far is a generalization of its predecessor, and includes its predecessor as a special case. The last, the projective transformation, merely preserves straightness if lines (collinearity of points). An even more general transformation (which is however not linear) is a general topological transformation, that does not even preserve straightness, but preserves only neighborhood relationships, i.e., preserved vicinity

III. KEYSTONE EFFECT

The keystone effect, also known as the tombstone effect, is caused by attempting to project an image onto a surface at an angle, as with a projector not quite centered onto the screen it is projecting on. It is a distortion of the image dimensions, making it look like a trapezoid, the shape of an architectural keystone; hence the name of the feature[3],[5]. In the typical case of a projector sitting on a table, and looking upwards to the screen, the image is larger at the top than on the bottom. Some areas of the screen may not be focused correctly as the projector lens is focused at the average distance only. The distortion suffered by the image depends on the angle of the projector to the screen, and the beam angle. The distortion (on a two-dimensional model, and for small focus angles) is best approximated by

$$\frac{\cos(\epsilon - \frac{\alpha}{2})}{\cos(\epsilon + \frac{\alpha}{2})} \quad (2)$$

where ϵ is the angle between the screen axis and the central ray from the projector, and α is the width of the focus[1],[2]. From the formula, it is clear that there will be no distortion when ϵ is zero, or perpendicular to the screen. The problem arises for screen projectors that don't have the depth of focus necessary to keep all lines (from top to bottom) focused at the same time. The problem can be solved by move the projector more to the center of the screen, if this does not interrupt vision tilt the screen in a small angle use some type of software on the projector (or computer controlling the projector).

IV. KEYSTONE CORRECTION

Keystone correction, colloquially also called keystoneing, is a function that allows multimedia projectors that are not placed perpendicular to the horizontal centerline of the screen (too high or too low) to skew the output image, thereby making it rectangular[4]. It is often necessary for a projector to be placed in a position outside the line perpendicular to the screen and going through the screen's center, for example, when the projector is mounted to a ceiling or placed on a table top that is lower or higher than the projection screen. Most ceiling-mounted projectors have to be mounted upside down to accommodate for the throw of the image from the lens, with the image rotated right-side-up with software.

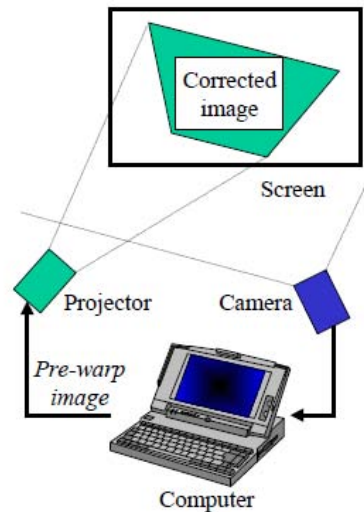


Fig 2. Setup Of Projector Camera System

"Keystoning" occurs when a projector is aligned non perpendicularly to a screen, or when the projection screen has an angled surface. The image that results from one of these misalignments will look trapezoidal rather than square. A distorted image is a distraction most presenters want to avoid. However, in some cases, there is nowhere else to place the projector. So what can you do? Early projectors did not have keystone correction features[7]. Projectors were usually found in fixed installations, so furniture and screens could typically be moved to accommodate. As projectors became lighter and more portable, the demand for an easier solution grew. Keystone correction is a feature included with many projectors that provides the ability to intentionally "distort" the output image to recreate the original rectangular image provided by the video or computer source, thus eliminating the skewed output that would otherwise result due to angled projection. This image manipulation is called vertical keystone correction. Vertical keystone correction also works if the reverse has happened and you need to tilt your projector downward instead of upward. While all projectors now have vertical keystone correction, horizontal keystone correction is much less common. Horizontal keystone correction is needed when the front face of the projector cannot be placed parallel to the screen surface.

V. ALGORITHM

The method to find homography has been described in the [8], we are describing how to find corners of the image taken and our algorithm to find largest area rectangle inside any quadrilateral.

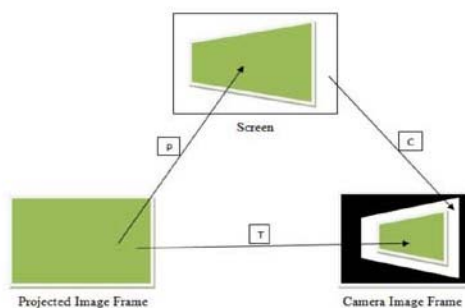


Fig 3. Homographies relating projector, camera and screen

Obtaining corners of screen. Project white or blue light on the screen with the help of projector. Obtaining corners of projected white image. Finding homography C relating camera and screen image. Finding homography T relating projector and camera image. Thus obtaining P (projector to camera) homography $= C^{-1}T$. Obtain correct image coordinates from global perspective by applying C^{-1} to image obtained in camera. Find the largest area rectangle that can be fitted inside this quadrilateral.

A. Image Corner Detection Method

We follow a very simple method to obtain corners of screen as well as projected white image. First of all we assume that whatever be the projected image the screen or white patch will always hold the centre of the whole image. In the next step, we obtain the edge of the image by using canny edge detection. Now taking 25 pixels above and below the centre, move in the horizontal direction towards right till we first encounter an edge. This

first edge is the right edge of image. Similarly move in the left direction till we get left edge. For top and bottom edge of image take 25 pixels to the left and right of centre and move in upper and lower direction respectively till we encounter first edge. Thus we can find equation of line from the two points obtained on each edge and intersection of lines gives corner point of the screen.

B. Finding Largest Area Rectangle Inside Any Quadrilateral

The brief idea about this algorithm is we first select any point close to the centre of image and move in a spiral pattern around that point till we face the obstruction. If suppose we get obstructed at some point then we stop moving along the direction in which we face obstruction. Following Figure demonstrates the method of finding the largest area rectangle.

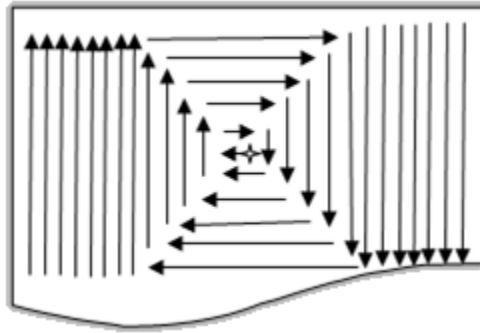


Fig 4(a). Finding largest area rectangle

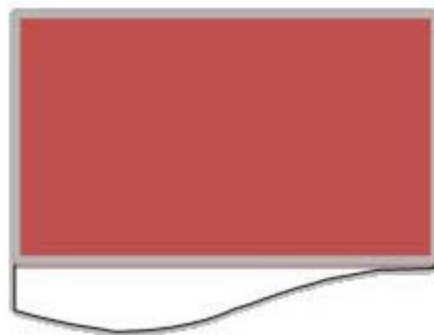


Fig 4(b). Largest rectangle area plotted

The algorithm that has been followed to obtain this result is explained below.

Convert the image in which we need to find largest rectangle into binary image by setting the level using graythresh in Matlab. Now estimate the corners of the area in which we need to perform our evaluation and from that calculate centre point. (The centre need not be exact we just need any point close to the centre.) Set row and column equal to 1 and counter to zero. Move left by 1 pixel and check if its 1. If its 1 proceed to step 5 else obtain different centre. Move upward by 1 pixel and traverse to right by pixels equal to no. of column. If all pixels encountered while traversing are 1 then increment row by 1 else return to previous position. Move to the right by 1 pixel and traverse downward by pixels equal to no. of rows. If all pixels encountered while traversing are 1 then increment column by 1 else return to previous position. Move downward by 1 pixel and traverse to left by pixels equal to no. of column. If all pixels encountered while traversing are 1 then increment row by 1 else return to previous position. Move left by 1 pixel and traverse upward by pixels equal to no. of rows. If all pixels encountered while traversing are 1 then increment column by 1 else return to previous position. Repeat step 5 onwards till you find that sum of row and column is not increasing. In the above algorithm sometimes it may happen that we will get area covered around centre point by a square or rectangle and it may not be biggest rectangle. To avoid this situation in step 2 we have to take few more points as centre point of our algorithm that can be near edges or near centre and finally find out which centre is giving biggest area. An example of an erroneous result is demonstrated below.

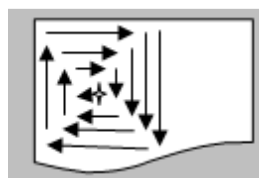


Fig 5. Error in output due to wrong center

We find corners of the image taken and our algorithm to find largest area rectangle inside any quadrilateral.

VI. CONCLUSION

Distance, angle, ratio of distance or hardly any geometry is preserved by projective transformation. Which causes keystoneing occurs. We find the centre of the whole image and the edge of the image by using canny edge detection. Another way to find largest area rectangle inside any quadrilateral by finding homography C relating camera and screen image and obtain correct image coordinates by applying C^{-1} to image obtained in camera. We proposed a method to achieve same in this paper but it may happen that we will get area covered around centre point by a square or rectangle and it may not be biggest rectangle

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