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A Decentralized Approach to Geometric Video Correction for Network-based Video Wall

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Abstract

This paper describes a decentralized approach to geometric video correction for networked client server based video wall with an art layout of heterogeneous displays. The proposed method is implemented on a mobile device, a video control server and multiple thin clients. The geometric mismatches due to such changes can be corrected even while the video wall is in operation. This proposed correction system is robust to change of positions or angles of the displays to some extent.

Keywords: *video wall, heterogeneous displays, geometric correction, artistic layout, mobile device*

1. Introduction

There has been an increase in demand for presenting high resolution videos on a large display in many fields because it can offer reality and immersion simultaneously. Video wall is an efficient and practical way to build a large screen. The screen of a video wall is usually composed of multiple smaller video displays, such as LCD, LED monitors or projectors [1-3].

When combining multiple displays to constitute a large screen, one needs to calibrate geometric deformation and characteristics such as white balance, luminance, color management and gamma correction for each display. Various calibration products have been introduced. The display wall calibration of NEC profiles peculiar characteristics among devices by applying various patterns [4]. CalMAN5 has added a function considering bezel features together [5]. Useful's video wall controller supports both grid and artistic layout of displays [6]. However, video wall forms a very high-priced product line in many fields such as advertising, public relations and disaster management.

Recently, the LCD video wall market is expanding, as the size of bezel has been reduced to less than 3 mm [7]. However, the diversification of LCD product line has several problems regarding maintenance. When an aged or malfunctioning display needs to be replaced, additional purchase may become difficult due to the product discontinuation. Heterogeneous displays have different bezel sizes, and also pixel sizes become different, as resolution becomes higher, compared to display’s physical size. Such a problem causes huge decline in video quality: discontinuity of objects among adjacent screens, or improper magnification or reduction. To minimize such quality decline, proper calibration should be conducted beforehand.

The layout of displays used in video wall can be categorized into two styles: grid layout and artistic layout. Artistic layout refers to a configuration of displays where each display can be placed in any position with any rotated angle in a video wall. If heterogeneous displays are used to form a video wall, different scale factors should be applied to the original sub-images in consideration of the geometric

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characteristics of each display[8]. In an artistic layout, sub-images should be rotated before being presented on a rotated display.

One of the biggest problems occurred during the operation of a video wall is the change of display configuration: replacement of the installed displays with new ones, and change of the position or tilted angle of displays, etc. Even a slight change in the layout configuration would cause the visual quality to deteriorate because of geometric mismatches among displays. In most of the client server based video wall, the server creates several sub-videos from a part of the original video and transmits each of them to the different clients. In such a case, it is not easy to cope with a sudden change of configuration. In this paper, a new decentralized geometric correction strategy is proposed to properly correct geometric mismatches without regenerating the sub-videos.

The proposed method can be used in both grid layout as well as art layout including heterogeneous displays. Using this method, one can correct the video mismatches caused by the geometric changes of display even while a video wall is in operation.

The rest of this paper is organized as follows. Section 2 explains briefly the architecture of the proposed geometric correction system. Section 3 describes the way to assign a part of the original image to each display for the preparation of creating sub-videos. Section 4 explains how to correct geometric mismatches using a mobile device. Finally, conclusions are drawn in Section 5 [9].

2. Architecture of the Proposed Geometric Correction Method

This section describes the architecture of the proposed decentralized geometric correction method. The proposed method is implemented on different modules: a display analyzer, multiple clients and a server. Figure 1 shows the architecture of the proposed method.

The display analyzer is responsible for measuring the geometric information of each display such as panel and bezel sizes, positions and tilted angles of displays. It also calculates scale factors as well as parameters related with the geometric characteristics of displays needed for calculating the size of the normalized image plane. The normalized image plane refers to a large virtual image containing all the displays in it. These parameters and scale factors of each display are sent to the server. The details of thereof will be explained in Section 3.

The server is comprised of a control server and a video distribution server [10, 11]. The control server makes the normalized image plane by using the parameters received from the mobile device and prepares clipped video images in consideration of each display. The control server also sends to each client the parameters needed to display its own video. Once clipped sub-video streams are created, they are encoded and streamed to each client by the video distribution server.

A thin client is attached to each display, which is implemented on a Raspberry Pi. The client is responsible for decoding the encoded streams transmitted from the video distribution server and rendering the video on the display by using the characteristic parameters transmitted from the control server.

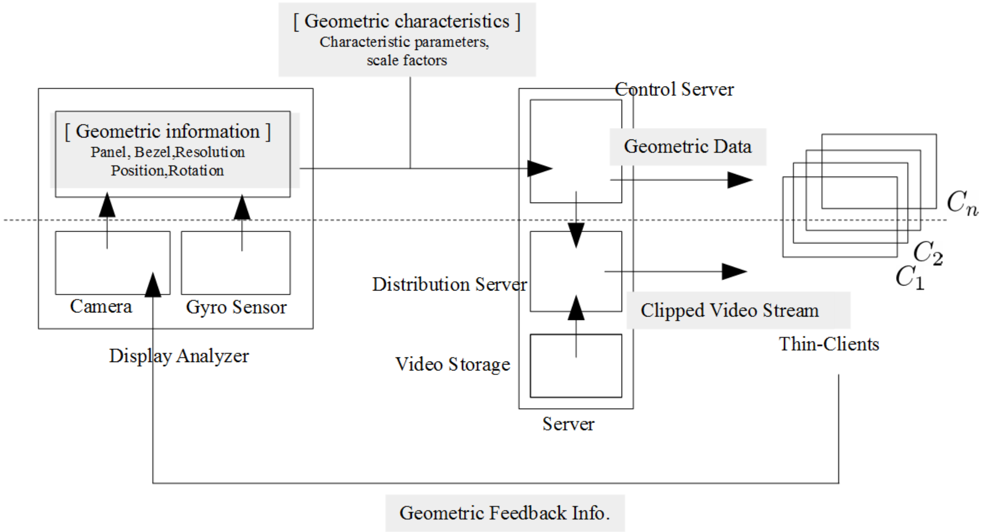


Figure 1. The Architecture of the Proposed Geometric Correction Method

3. Calculation of Enlarged Areas for Displays

In a networked client server based video wall system, video distribution server transmits compressed clipped video streams to each client which is attached to a display. In general, the number of pixels in an original video image is smaller than that in the whole area of video wall screen, so single display presents only a part of the original video. This is called a sub-video in this paper. For the sake of convenience, in this paper, a normalized image plane is defined as a virtual image which maps the original image data into the video wall screen. The normalized image plane is similar to the scaled image in [8].

Assume that a video wall screen consists of K component displays. Let k be an integer such that $1 \le k \le K$. Let w_p^k and h_p^k be the width and the height of the $k-$th display panel in cm, respectively. Let w_r^k and h_r^k be the numbers of pixels of the $k-$th display along the horizontal and the vertical direction, respectively. Let w_x^k and h_x^k be the sizes of a pixel of the $k-$th display along the horizontal and the vertical direction in cm, respectively. Then, w_x^k and h_x^k can be expressed as

$$w_x^k = \frac{w_p^k}{w_r^k}, \quad (1)$$

$$h_x^k = \frac{h_p^k}{h_r^k}. \quad (2)$$

Let $w_{\rm ppc}^k$ and $h_{\rm ppc}^k$ be the numbers of pixels per centimeter(PPC) of the $k-$th display along the horizontal and the vertical direction, respectively, which can be represented as follows.

$$w_{\rm ppc}^k = \frac{w_r^k}{w_p^k} = \frac{1}{w_x^k}, \quad (3)$$

$$h_{\rm ppc}^k = \frac{h_r^k}{h_x^k} = \frac{1}{h_x^k}. \quad (4)$$

Table 1 shows some of the characteristic parameters of several example displays. It can be seen that the PPCs are different from one other by different display models. For example, the values of $w_{\rm ppc}$ vary between 18 and 85. Because of such differences, the sizes of the same objects presented on the displays having the same resolution but different sizes are different from each other.

Table 1. Some of the Characteristic Parameters of Several Example Displays

Display model	Resolution	Screen size (cm)	Panel size (cm)	w_{ppc}	h_{ppc}	PPC ratio
LG27MB85Z	2560 x 1440	68.5	59.6 x 33.5	42.95	42.98	0.99
27M45D	1920 x 1080	54.6	47.6 x 26.7	40.33	40.44	0.99
W1943TE-PF	1360 x 768	47.1	41.1 x 23.2	33.09	33.1	0.99
Philips 4065UC UHD	3840 x 2160	100.3	87.8 x 48.5	43.73	44.53	0.98
31MU97	4096 x 2160	78.7	69.9 x 36.7	58.59	58.85	0.99
UP271K	5120 x 2880	68.3	59.6 x 33.5	85.9	85.9	0.99
32LX530H	1366 x 768	80.0	69.0 x 39.0	19.79	19.69	1.01
UN48J5920AF	1920 x 1080	121	105.6 x 60.4	18.18	17.88	1.01

Figure 2 shows an example of an original image and the corresponding scaled image containing three displays, where the scaled image is obtained with the method in [8]. The original image is magnified to the size of a scaled image to cover all the component displays.

Let w_n and h_n be the numbers of pixels in the scaled image along the horizontal and the vertical direction, respectively. w_n and h_n are defined as follows, respectively.

$$w_n = \max(w^1_{\text{ppc}}, \cdots, w^K_{\text{ppc}}) \times w_{\text{wall}} \tag{5}$$

and

$$h_n = \max(h^1_{\text{ppc}}, \cdots, h^K_{\text{ppc}}) \times h_{\text{wall}} \quad , \tag{6}$$

where w_{wall} and h_{wall} are the lengths of the large screen of the video wall in cm, respectively.

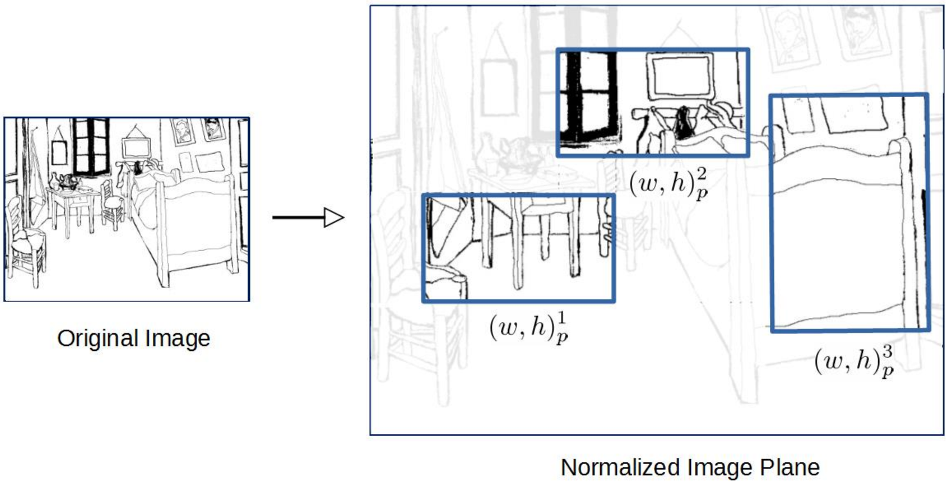


Figure 2. An Original Image and the Corresponding Scaled Image

It is noted that [8] assumed that no displays rotate. Consider the case when a display rotates while the others do not. In this paper, we assumed that the PPC of a rotated display remains unchanged. Instead of making a rotated sub-video for the rotated display, the video distribution server transmits an enlarged sub-video to the client. Then the client is responsible for generating rotated sub-video from the enlarged sub-video in consideration of the rotation angle of the display. The advantage of this approach is twofold: The one is that it decentralizes the computational burden of the video distribution server to the clients so that the number of clients may be increased. The other one is it can make the correction system to be robust to position or angle changes of the displays to some extent in that the geometric mismatches due to such changes can be corrected even while the video wall is in operation.

The rectangular-shaped sub-image in the normalized image plane which includes the rotated display in it is called an enlarged image in this paper. Figure 3 shows the relationship between a rotated image and the corresponding enlarged image. In this figure, the inscribed rectangle is the display rotated about the bottom-left corner by a counterclockwise angle θ and the outer rectangle is the enlarged image.

Let w_r and h_r be the number of pixels in the enlarged image along the horizontal and the vertical direction, respectively. Let w_r' and h_r' be the number of pixels in the enlarged image along the horizontal and the vertical direction, respectively. If the original image rotates counterclockwise by θ, we have the following relation:

$$w_p' = h_p \cos\left(\frac{\pi}{2} - \theta\right) + w_p \cos\theta \quad , \tag{7}$$

$$h_p' = h_p \cos\theta + w_p \cos\left(\frac{\pi}{2} - \theta\right) \quad . \tag{8}$$

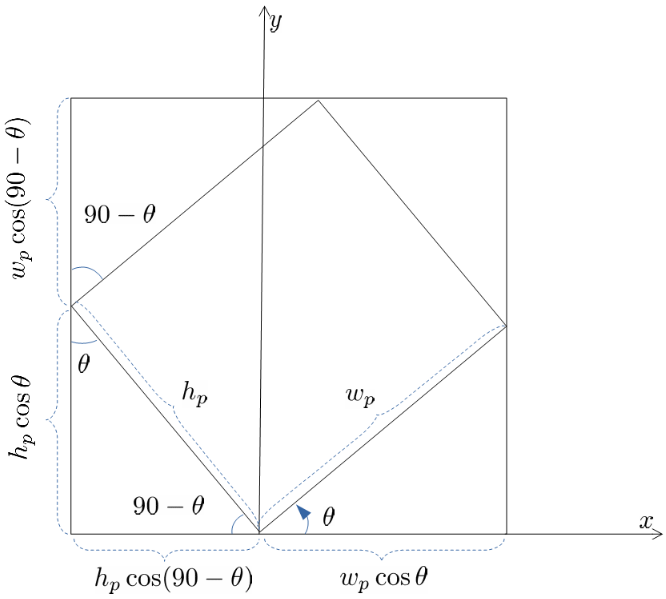


Figure 3. A Rotated Image and the Corresponding Enlarged Image

The boundary of the enlarged image is shown as a dashed box in Figure 3. It is noted that the image clipping is performed on the normalized image plane not on the original image. In Figure 4, it can be seen that the dashed boxes are bigger than the displays. This is because some amounts of margins are added to the actual display sizes. These margins enable the clients to adjust the area of the video to be presented on the display, even the tilted angle or the position of a display changes to some extent, without recreating clipped videos. The more the margin increases, the more robust to the geometric change of displays the correction system is but the bigger the bit rate of a compressed sub-video becomes.

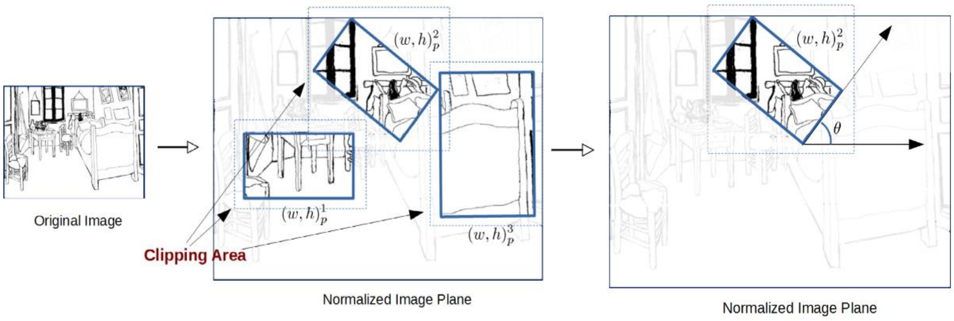


Figure 4. An Example of Enlarged Video Areas in the Normalized Image Plane

4. Correction of Geometric Mismatch using Mobile Device

In this paper, the display analyzer is implemented on a mobile device. To use a mobile device as the display analyzer is cost effective because it is equipped with most of the sensors for this purpose, such as a camera and gyro sensors. Figure 4 depicts a service scenario where the display analyzer installed on a mobile device collects some characteristic parameters of displays of a video wall and each of the clients adjusts its own video in accordance with the parameters transmitted from the display analyzer via the video control server, while the video distribution server transmits the clipped sub-videos to each client.

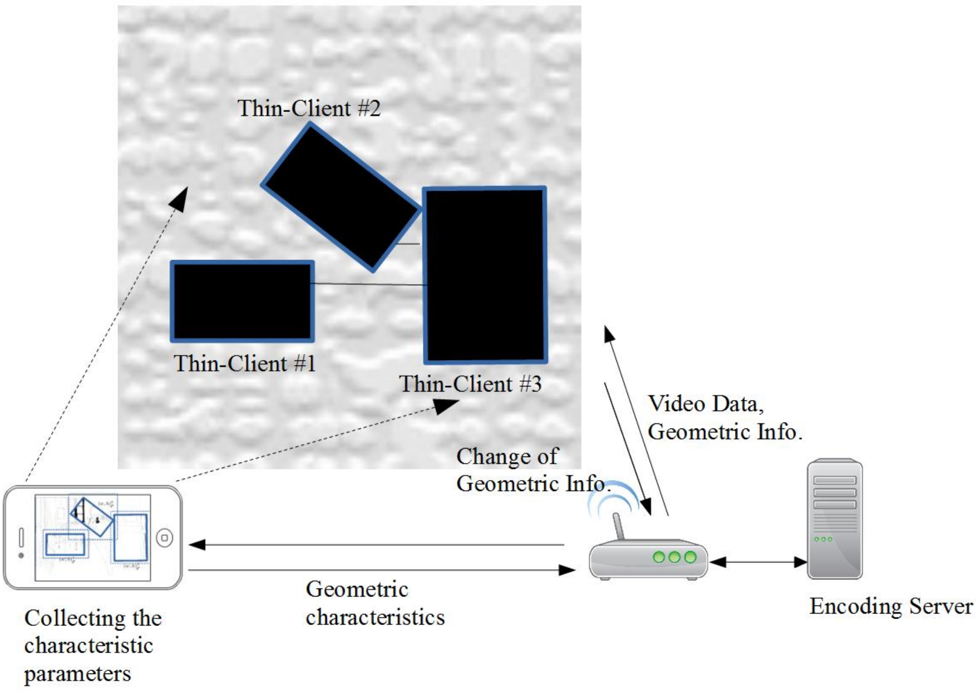
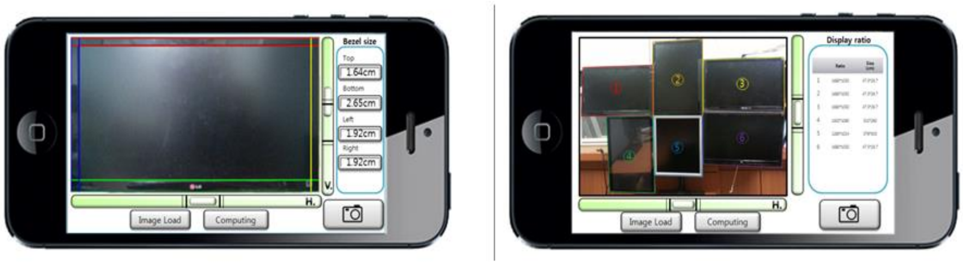


Figure 5. Service Scenario for Collecting the Characteristic Parameters of Displays and Correcting Geometric Mismatches

Figure 6 (a) shows the procedure for collecting characteristic parameters of displays, where physical sizes and resolution of a display are collected manually. Based on the inputted information, bezel's physical size and pixel ratio are automatically calculated. This is one of the pre-procedures not to cause screen distortion.

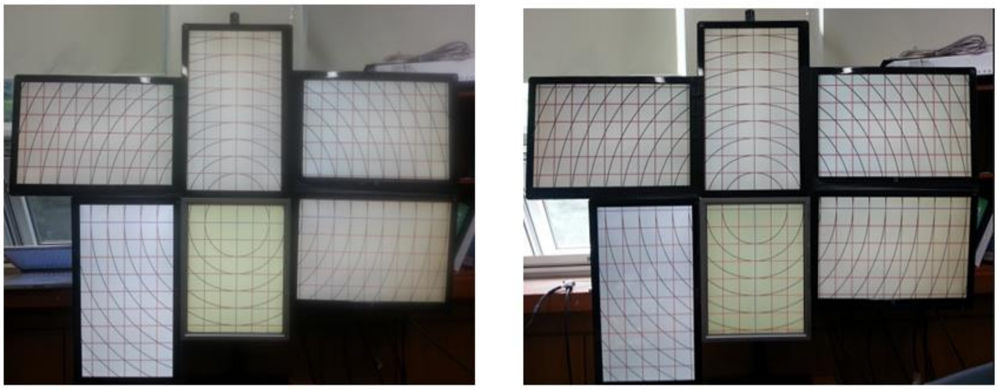
After the display's basic characteristic parameters are identified, the rest of the characteristic parameters of displays can be automatically obtained as shown in Figure 6 (b). Through this, relative location and enlarged image areas among displays can be calculated.



(a) Bezel Detection **(b) Alignment of Displays**

Figure 6. Collection of Characteristic Parameters of Displays through the Display Analyzer on Mobile Device

Figure 7 shows an actual video test for geometric correction using an artificial test pattern. In Figure 7 (a), it can be seen that all the videos on each display are not aligned. After repeating margin adjustment using the feedback from the display analyzer, the clients succeeded to present correct geometrically corrected videos as in Figure 6 (b) [12].



(a) Before Geometric Correction **(b) After Geometric Correction**

Figure 6. Geometric Correction Using an Artificial Pattern

Figure 8 shows the screen of actual video service, before and after geometric correction using a natural image. It can be seen that the severe size distortion of a structure is revealed.

5. Conclusions

Video wall is an attractive way of presenting video content on a group of off-the-shelf displays. One of the biggest problems faced during the operation of a networked client server based video wall is the change of display layout configuration because even a slight change in the layout configuration would cause geometric mismatches among displays and this in turn makes the visual quality to deteriorate.

As a solution to such a problem, in this paper, a decentralized geometric video correction method is proposed. The proposed approach is implemented on a mobile device, a video control server and multiple thin clients. Some test results show that the proposed approach is robust to position or angle changes of displays to some extent in that the geometric mismatches due to such changes can be corrected with ease even while the video wall is in operation.

Even though the test results presented in this paper have shown that the potency of the proposed approach good, it has to be further developed. The automation of display analysis could increase the efficiency of the operation.

(a) Before Geometric Correction **(b) After Geometric Correction**

Figure 8. Comparison of a Natural Image before and after Geometric Correction

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