Color Difference Evaluation for Transmitted Images of Surveillance Cameras

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ABSTRACT

Surveillance cameras equipping the pan-tilt-zoom (PTZ) feature are widely utilized in various domains due to their versatile functionalities. However, the measured colors of environment from cameras may differ during transmission. By conducting experiments, this study aims to examine these differences, offering valuable insights into color management within surveillance camera applications.

1. Introduction

PTZ cameras, which equip pan, tilt, zoom and smoothly movement features, are extensively used in various applications such as video surveillance systems[1]. In the era of digital media proliferation, achieving true and accurate color representation holds significant importance in image transmission[2]. However, during the process of the transmitted images from a PTZ camera to a display, color discrepancy may occur. It is crucial to minimize the color differences between the displayed image and the original colors of objects to ensure the faithful representation of objects[3]. Inaccurate control particularly for color transformation and processing may adversely affect the final perceived colors on a display. To evaluate these color differences, this study conducted a series of experiments and analyses.

2. Experiment

By following the experimental framework in Figure 1, after capturing the images, we conducted comprehensive measurements on both the captured images and a reference target as well as the color checker. These measurements will induce multiple sets of data for subsequent analysis and calculations.

These data can help us obtaining specific data and quantitative indicators regarding color differences, and allowing us to get deep understanding of the characteristics of color performance of the PTZ camera during image transmission. Figure 2 shows the schematic diagram depicting the configuration of the experimental setup.

Fig. 1 Flowchart of Experimentation System

Fig. 2 Experimental configuration figure

2.1. Experimental material

First of all, we captured images for the 24 X-rite color checker by the PTZ camera, and the color checker was well placed in a specific environment as in a lighting box with standard D65 illumination in a dim room. To compare color differences under different conditions, we used three different combinations of parameters for capturing, including automatic white balance (auto-white balance only), automatic exposure (auto-exposure only), and both of them (as notated as full auto). Furthermore, we captured images at six different zoom levels for each parameter combination, which includes 1x, 2x, 4x, 8x, 16x, and 32x. To capture images at higher zoom levels, the PTZ camera will be positioned at approximately 5 meters away from the reference target.

After obtaining the 18 untreated images, we created a control group by embedding an ICC profile into each image. The purpose of this control group is to examine whether embedding an ICC profile with color correction...
capabilities into the images results in smaller color differences compared to the original images. Consequently, we ultimately measure a total of 36 images. Figure 3 displays one of the original images, which was captured with a 16x magnification under the three parameters.

2.2. Data Measurement

To assess the color differences in PTZ camera images after transmission to the display, we employed professional color measurement tools to measure the images on both the original objects and the display. Each image involves 24 data sets. However, due to the inability to measure images with a 1x magnification factor captured under the settings of automatic exposure and auto parameters, we excluded six of these images. In the end, we collected a total of 720 data sets, which were used to calculate color differences. The results of the color difference calculations were utilized to assess the color fidelity of the images during transmission, further confirming the effectiveness of the color representation.

3. Result

Before conducting comparisons, we used the CIE ΔE94 formula to calculate the average color deviation from the 24 colors for each image, which was then used for subsequent comparisons. All average values of color difference are shown in Tables 1-3.

### Table. 1 average color difference values of full auto

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
<th>2X</th>
<th>4X</th>
<th>8X</th>
<th>16X</th>
<th>32X</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>original</td>
<td>30.22</td>
<td>10.17</td>
<td>13.57</td>
<td>8.74</td>
<td>10.01</td>
<td>14.54</td>
<td>13.94</td>
</tr>
<tr>
<td>Embedded ICC profile</td>
<td>30.34</td>
<td>8.04</td>
<td>11.25</td>
<td>7.58</td>
<td>9.46</td>
<td>13.33</td>
<td></td>
</tr>
</tbody>
</table>

### Table. 2 average color difference values of auto-white-balance only

<table>
<thead>
<tr>
<th></th>
<th>Auto white balance</th>
<th>2X</th>
<th>4X</th>
<th>8X</th>
<th>16X</th>
<th>32X</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>original</td>
<td>44.40</td>
<td>29.55</td>
<td>22.59</td>
<td>7.68</td>
<td>10.38</td>
<td>22.92</td>
<td></td>
</tr>
<tr>
<td>Embedded ICC profile</td>
<td>44.18</td>
<td>29.73</td>
<td>22.94</td>
<td>5.95</td>
<td>8.63</td>
<td>22.28</td>
<td></td>
</tr>
</tbody>
</table>

### Table. 3 average color difference values of auto-exposure only

<table>
<thead>
<tr>
<th></th>
<th>Auto exposure</th>
<th>2X</th>
<th>4X</th>
<th>8X</th>
<th>16X</th>
<th>32X</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>original</td>
<td>33.60</td>
<td>10.77</td>
<td>12.56</td>
<td>10.07</td>
<td>11.60</td>
<td>15.72</td>
<td></td>
</tr>
<tr>
<td>Embedded ICC profile</td>
<td>33.88</td>
<td>9.35</td>
<td>10.52</td>
<td>8.80</td>
<td>11.14</td>
<td>14.74</td>
<td></td>
</tr>
</tbody>
</table>

Overall, based on the observation of average color difference shown in Fig. 4, the performance ranking for the three different parameters is as follows: "full auto" performed the best, followed by auto-exposure, and lastly, auto-white-balance. Additionally, for each camera parameter, whether considering individual data or the overall average, images with embedded ICC profiles generally exhibited smaller color differences compared to the original images.

![Color difference of three parameters](image)

Fig. 3 The 16x magnification image, (A): Auto; (B): Auto white balance; (C): Automatic exposure
Among all magnification levels, images magnified at 2x showed the most noticeable color differences as shown in Fig. 5, whose color differences exceed 30 under all conditions. By contrast, images magnified at 16x had the lowest color deviations, whose color differences values were in a range from 5.95 to 10.07 under various conditions.

4. Discussion
The research design, as well as analysis methods, of this study aims to provide insight into the color performance of PTZ cameras during image transmission. The current research findings indicate that using the parameters of full-auto results in smaller color differences compared to other parameters. Additionally, embedding an ICC profile contributes to color restoration. However, concerning the magnification factor, employing excessively low magnification can lead to increased color differences.

5. Conclusion
Through these efforts, we anticipate in improving the color reproduction of PTZ camera images. It will be not only to enhance the development of relevant technologies, but to facilitate the progress in application areas such as visual monitoring, as well as providing specific guidelines and solutions for color management and display effects in relevant application areas.

References