The Influence of Reflective Screen Color and Surface Film Treatment for Single-Sided Holographic Projection on Imaging Quality

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Abstract

This study explored the effects of reflective screen material color and film treatment in holographic projection on image quality. Employing an experimental approach, algorithmic analysis of images captured after projection was conducted to examine image quality. Image analysis was performed using OpenCV software, focusing on quantifying values of average color (RGB), contrast, sharpness, and saturation. The results revealed that changes in the reflective screen material color led to a decrease in average RGB values, by approximately 50%, compared with the transparent colorless screen. A light brown colored material demonstrated more satisfactory sharpness performance compared with the transparent colorless and black color screens. However, differences in contrast and saturation among different colored screens were not particularly noticeable. Regarding film treatment, a decrease in average RGB values for black and dark silver surface films was observed. However, light black and dark silver surface films showed a significant improvement in sharpness. Differences in contrast were not pronounced, and saturation slightly increased after film treatment. The experimental findings further showed that as the thickness of the reflective screen increased, ghosting and blurring became more noticeable at image edges. Nevertheless, tinted materials and film treatment reduced ghosting and blurring. Film treatment with low light transmittance increased surface reflectivity, which resulted in a glare effect around the images on the reflective screen, affecting the viewing experience. The results of this research may be helpful for understanding image qualities and the setting up of holographic projection reflective screens.

Keywords:

Film treatment; holographic projection; openCV; reflective screen.

Highlights:

- Apply experimental methods and software to analyze image quality.
- Colored reflective scree has little effect on contrast and saturation.
- Colored or film treatment of reflective screen can improve the image sharpness.
- Reflective screen surface film treatment can enhance sharpness performance.
- Colored reflective screens can improve the overlay and blur at the image edge.

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1. Introduction

Holographic projection is becoming increasingly popular in commercial settings, and display methods are becoming increasingly diverse, as incorporating holographical technologies in addition to conventional sound and light effects shatters the limitations of traditional physical stage performances. Holographic projection provides a three-dimensional viewing mode different from conventional flat imagery, creating highly realistic and convincing spectacles that challenge viewers' visual perceptions (Que and Huang, 2011). It offers a distinctive viewing experience by integrating real objects with virtual images, and has become a common feature in modern digital display technology. Zhou and Zhang (2020) pointed out that holographic projection technology has been fully used in expositional activities, providing people with a new visual experience that is in the interactive display field.

Holographic projection display systems come in a variety of forms, including pyramid-shaped cone and single-sided display box, and have two main parts: an image projection device, which typically comprises a display screen or a projector and a reflective screen that shapes the virtual images. The most common form is a four-sided pyramid (Fig. 1), but in some cases, one-sided holographic projection is also used in performance areas, as in Fig. 2. Under typical circumstances, the reflective screen is a thin transparent panel set at a 45° angle from the display screen. This is because, according to the principle of reflection, when the incidence angle is equal to the reflection angle, viewers can perceive the projected images on the screen in their original proportions, but with the left and right sides of the projection reversed (Tenium Digital Technology, 2023)

Fig. 1. Four-sided pyramid display
(Source: photo by the author)

Fig. 2. Single-sided display
(Source: photo by the author)

In some situations, the reflective screen may exhibit slight coloration or have surface film treatments such as adhesive patterning. It is believed that different material colors of the reflective screen and the film treatments on the reflective surface should cause changes in image quality, but most people cannot distinguish the differences with just the human eye.

This study explores the influence of reflective screen material color and film treatment in holographic projection on image quality. The results of this exploration are expected to contribute to the control and enhancement of basic image quality variables during the setup of holographic projection displays, and to a deeper understanding of quantitative differences in image qualities. In order to clearly present the overall concept of this research, the concept flow of this image quality research is illustrated in Fig. 3.

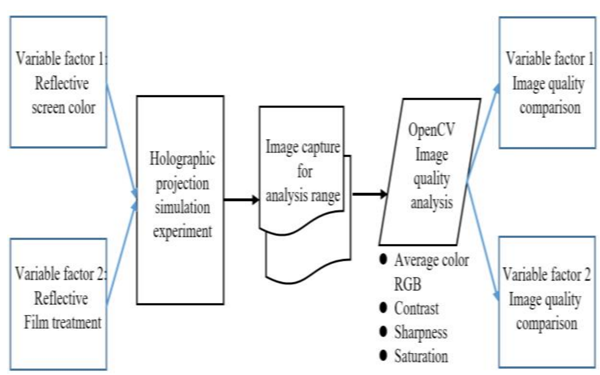


Fig. 3. Concept flow for this image quality research

1.1. Research purpose

There are numerous factors that can affect the image quality on a holographic projection's reflective screen, such as external environmental factors, the angle of the reflective screen, and the intensity of the projection screen's light source. This study focused on two of them, namely reflective screen material color and surface film treatment. Generally, the reflective screens used for holographic projection are made of transparent colorless materials. Transparent materials may have a slight color tint or undergo surface film treatment. This study maintained the control variables, such as external environmental factors and projection device factors, steady and defined the material color and surface film treatment of the transparent reflective screen as independent variables while investigating changes in image quality. The objectives of this study were as follows:

1. Analyze the quantified difference of reflective screen material color on image quality.
2. Examine the effect of surface film treatment on image quality.
3. Investigate the varieties of marginal images on the reflective screen under the influence of material color and surface film treatment through image comparison.

1.2. Research scope and limitations

To facilitate effective control and simplify the influence of independent variables, we employed a holographic projection device with a single-sided configuration for the experiment because this configuration is simpler than other configurations. The research scope and limitations are described as follows.

1. Considering that the potential interactive interference caused by external environmental factors and multi-sided imaging may hinder image comparison and analysis, multi-sided configurations were not included within the research scope.
2. In practice, holographic projection venues often feature ambient background lighting; thus, in the experimental environment, background ambient light was set to a diffused yellow light at 100 Lux for simulating exhibition background conditions.
3. Among the multiple aspects relating to image quality analysis, this study focused on average color (RGB) values, contrast, sharpness, and saturation.
4. This study adopted an objective assessment approach, using image algorithms for quantitative image quality analysis. Subjective evaluation methods were not included within the research scope.

2. Literature review

Most of the research on holographic projection in recent years focuses on discussions of technology development and applications; papers discussing the basic research on image quality of holographic projection are few to none. This is one of the important motivations for conducting this research. The literature review first explores the optical principles of holographic projection, then discusses the content of visual image quality. The last part reviews image quality evaluation methods and the use of algorithmic tools for image analysis.

2.1. Optical principles and structure of holographic projection

In fact, holographic projection is not new technology. John Henry Pepper, a faculty member of the Royal Institution, used holographic projection during a stage play in the mid-19th century. He employed a sheet of glass to project ghostly images onto the stage, creating a phantom-like effect. This visual effect created through the projection of images using glass and a specific light source was known as Pepper’s Ghost (Richardson and Wiltshire, 2018) and serves as the origin of holographic projection. Through reflection, when people observe an object in front of a mirror, they see an identical virtual image on the opposite side of the reflection plane, positioned vertically to the normal line behind the mirror surface (Mao, 2006). The optical principle of plane mirror reflection is illustrated in Fig. 4.

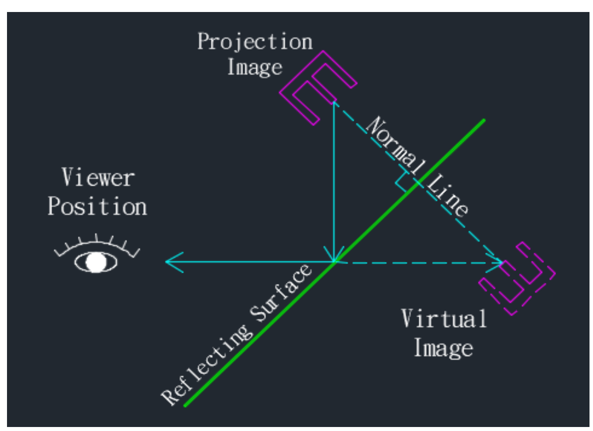


Fig. 4. Schematic diagram of the mirror reflection principle of holographic projection (Source: drawn by the author)

2.2. Visual image quality evaluation

Image quality evaluation can be conducted through two approaches. One involves participants providing direct, intuitive judgments after engaging in image experiments. However, this is a subjective approach because its results are influenced by the subjective preferences of the participants. The other approach involves performing physical and quantitative objective assessments using computer algorithms. The latter approach can rapidly produce quantitative results; however, the outcomes may not necessarily align with subjective perceptions of human beings (Morovic and Luo, 2001).

Tanaka et al. (2020) investigated the effects of luminance, image contrast, and image sharpness on visual appearance. Tsai and Kuan (2009) required participants to subjectively evaluate image quality on the basis of three physical attributes: saturation, sharpness, and contrast. Johnson (2005) argued that the overall perception of images is influenced by the color ambience created by complex spatial stimuli and that characteristics such as color, clarity, contrast, and granularity can serve as criteria for assessing image quality.

Liu (2010) stated that conventional objective methods for assessing image quality are not flawless and that the visual clarity perceived by the human eye is not fully considered. By employing a modified evaluation algorithm that enhances the observer's perception of image clarity, Liu achieved a more precise assessment of clarity. In addition, Liu incorporated luminance, contrast, clarity, and noise for image quality evaluation and presented a refined analytical approach for image evaluation. Sun et al. (2022) mentioned that the visual discomfort factors, which include disparity, terrain texture, luminance, and amplitude spectrum, can affect visual perception.

Fu et al. (2023) investigated the effects of depth in display environments and display device resolution to examine the relationship between viewing depth and image clarity. Yang (2008) identified factors influencing image quality and demonstrated that resolution, noise, color reproduction, contrast, and sharpness influence image quality. The evaluation of the effectiveness and quality of digital image restoration can be achieved through computer algorithms, and the evaluation results are basically consistent with perceptual test results (Chambah, 2008).

According to Tsai and Kuan (2009) and Johnson (2005), image quality is associated with color, sharpness, contrast, saturation, and signal granularity. Considering the objectives and requirements of the present study, this research study set four criteria for image quality analysis: changes in the average color of R/G/B, contrast, sharpness, and color saturation. The average color R/G/B refers to the composition of the three primary colors forming the average color of the image.

2.3. Image quality evaluation software

This study applied a simulated experimental approach to obtain images formed on the reflective screen of a holographic projection display. Objective algorithmic software was used to analyze the variations in image quality under different variables. Three types of image analysis software were reviewed for this study.

2.3.1. ImageLab

This software, developed by Bio-Rad Laboratories, is an image recognition tool designed to directly control images, capture images, and adjust image content for quantitative analysis. It supports image overlay functions, can export files in TIF or JPG formats, and is particularly suitable for analysis of dynamic image captures. The software has a grid positioning feature that is often used for analyzing molecular quantities, migration ranges, and image differences. The software is commonly employed for micro dynamic image observation and image capture (Bio-Rad Laboratories Inc., 2023). However, the features and content of ImageLab do not fully meet the image quality evaluation objectives of the present study.

2.3.2. Image color summarizer

This is an analysis software that extracts images from geometric graphics for color analysis. It can provide comprehensive information about color combinations, color content proportions, and RGB compositions. Moreover, it can offer detailed color pixel data for pattern analysis, providing a thorough understanding of color-related information (Leizersoft website, 2023). However, it lacks the capability of providing detailed information of image quality aspects such as contrast, sharpness, and saturation, making it unsuitable for this study.

2.3.3. OpenCV

OpenCV is a program developed for an internal project by Intel Corporation. It offers an open-source programming language platform for users to engage in the development of image recognition software. Equipped with an image recognition function library, OpenCV provides various features required for image quality recognition and analysis. It has robust computational capabilities, and its built-in image analysis function database can be used for quantitative characteristic analysis of image quality. Users can input various file formats for computation and obtain quantitative data on desired image properties. In recent years, various artificial intelligence image algorithms and recognition systems have been developed (OpenCV, 2023). It seems more suitable for use in the present study than the other software reviewed as it can calculate RGB color values, contrast, sharpness, and saturation.

3. Research method and operation

To investigate the effects of reflective screen material color and surface film treatment on holographic image quality, an experimental approach was adopted. Variables were manipulated under specific conditions and differences in image quality were observed (Kuan et al., 2010). To effectively control variations in the independent variables and investigate the effects of variables on image quality, we established a dedicated research space with a physical projection experimental chamber constructed of wood, measuring 40 cm in width, 60 cm in height, and 30 cm in depth.

The inner walls of the experimental chamber were matte black, which minimized internal wall reflections and mitigated the effect of wall reflections on projected images. The reflective screen within the experimental chamber was made of transparent colorless acrylic measuring 30 cm in width, 35 cm in height, and 2 mm in thickness. Details regarding the overall experimental procedure and operational variables are explained in the following subsections.

3.1. Experimental environment settings

Holographic projection displays usually perform better in dark environments. However, in practical settings, displays are often held in environments with some ambient background light rather than in complete darkness. In general, holographic projection is conducted in low-illumination conditions with yellow diffused light. Thus, in this study, we placed the experimental chamber in a dedicated research room. The background light source consisted of yellow diffused light generated by LED ring lights (color temperature 3000 K), with an illuminance set at 100 Lux. The illuminance measurement position was set at the edge of the experimental chamber in front of the reflective screen. The image projection screen was a Microsoft Surface 14-inch tablet with brightness set to 100%. The experimental projection image was set to an RGB stereogram to facilitate subsequent research on the comparison of changes in average color RGB values under various variables. Image capture on the reflective screen was performed using a digital camera (Canon 650D), which was set at the same position and height throughout the entire experiment. A diagram of the experimental chamber is shown in Fig. 5.

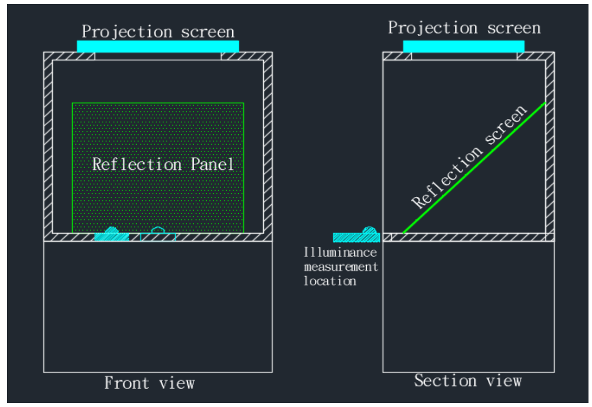


Fig. 5. Schematic diagram of the single-sided holographic projection experimental chamber

3.2. Experimental operation process

In the experimental imaging operations, only one variable was adjusted in each instance of image capture, which was accomplished with a digital camera. The image capture distance and height were adjusted to imitate a typical viewer's viewing angle and distance. To avoid interference from camera equipment, the setup remained unchanged once positioned until the end of the image capturing process. Photoshop was applied to extract the area for analysis from each image. The extracted areas were consistently positioned within the same range and location. Subsequently, the extracted images were imported into OpenCV to obtain quantitative image quality data, which were analyzed and compared. The overall experiment and image quality analysis process had five stages (Fig. 6). The image input operation interface for OpenCV analysis software is as shown in Fig. 7.

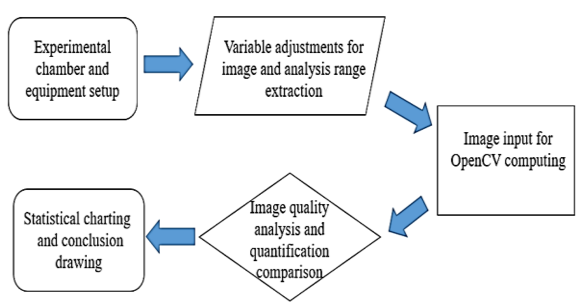


Fig. 6. Experiment and research operation process

Fig. 7. OpenCV image analysis operation interface

3.3. Reflective screen material control variables

As part of a series of studies on factors affecting the quality of holographic projections, this study primarily focuses on the effect of reflective screen material color and film treatment on image quality. Other factors that affect holographic projection image quality were considered as control variables for the test. In other words, the screen material color and film treatment on the reflective screen were set as independent variables for the experimental simulations. The variables for testing items are as follows:

1. Variations in the material color of the transparent reflective screen (transparent/light brown/dark brown/light black/medium black).
2. Film treatment on the surface of the transparent reflective screen (none / light black / dark black / dark silver).

3.4 Image quality analysis

As discussed before, this study examined image quality from four major aspects: changes in (1) average RGB color values, (2) contrast, (3) sharpness, and (4) saturation. The numerical range and description of these image quality aspects for OpenCV outlined on the software database by the STEAM learning network are indicated as follows:

1. Average RGB

Colors in an image can be observed by quantifying the composition of the three primary colors: RGB. Color variation is examined through changes in the average composition of RGB. In the OpenCV algorithm, the numerical range for average RGB is defined between 0 and 255. A value of 0 indicates white, whereas a value of 255 represents black. Higher numerical values signify darker colors. (numeric range 0~255)

2. Contrast

Contrast shows the extent of variation between the high and low tonal levels within an image. In the algorithm, the contrast value is calculated on the basis of the difference in brightness levels between the brightest and darkest areas in the image. It represents the degree of grayscale difference in the image. A higher contrast value indicates a larger contrast, whereas a smaller value indicates a smaller contrast. Generally, when the contrast is low, the brightness difference in the image is more subtle. (numeric range 0~127.5)

3. Sharpness

Sharpness refers to the degree of clarity of edges within an image. In OpenCV, the Laplace gradient function calculates the sharpness by detecting edges and converting them to grayscale. It detects contrast and pixel differences through a second-order differential algorithm. A higher sharpness results in a clearer image. In general, a sharpness value above 200 indicates a clear image. A value between 100 and 200 suggests less clarity, and a value of less than 100 indicates a blurred state. (numeric range 0~255)

4. Saturation

Saturation represents the degree of color purity or richness, indicating how vivid or intense the colors are within an image. Saturation is sometimes referred to as color purity. This study recognized images using their primary colors. Through calculations and conversion, colors were transformed into hue, saturation, and value (HSV). The quantified value of saturation was obtained from the calculated HSV data. A higher numerical value indicates a higher color saturation, whereas a lower value suggests a more subtle color intensity. (numeric range 0~255)

4. Data analysis and results

A series of experiments was conducted to examine the effects of reflective screen material color and film treatment on image quality. Through calculations by the OpenCV image quality function library, relevant quantified quality data were obtained, and calculated results of every variable are shown in the following tables and figures. The analysis results are discussed and explained in the following sections.

4.1. Influence of reflective screen material color

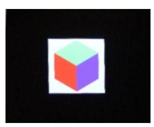
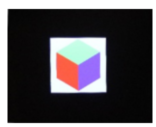
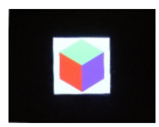
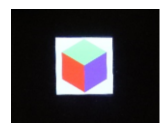
In this study, the original reflective screen used for the single-sided holographic projection device was made of transparent colorless acrylic. This study selected four colors (light black, medium black, light brown, and medium brown) in addition to the original colorless material. The quality of images projected on these five reflective screens was compared and analyzed.

By the average color RGB value in Table 1, the colorless material exhibited a higher average RGB value than the other colored materials. The RGB values for the colored acrylics were similar at approximately 1/2 of the value for the colorless acrylic. By the theoretical formula calculated according to RGB value, the results show that, when the reflective screen material has a black or brown tone, and when dark colors occupy a considerable proportion of an image, the pixel intensity values of the image in grayscale, after being divided by total pixel intensity, lead to lower average RGB values in darker images. This explains the lower average RGB values for darker colors in a reasonable and understandable manner.

Observing contrast and saturation trends in Fig. 8, the differences among the 5 material colors were not particularly apparent. Although the contrast values for the black and brown acrylics were slightly higher, by approximately 10, compared with the contrast range of 0 to 127.5, there is not a particularly big difference. The colorless and black acrylics yielded relatively similar results in saturation. Because the background color of the experimental box was set as black, with the colorless reflective screen material against this black background, it is reasonable that the value of the colorless acrylic was close to that of the black acrylics.

From Table 1's analytical values of sharpness, it is obvious that reflective screen materials with a black or brown tone exhibited superior sharpness compared with the colorless material. The performance of the brown acrylics was even greater than that of the black acrylics. Overall, concerning the sharpness performance within the brown color tones, the light brown color displayed more satisfactory results than the dark brown color. In terms of sharpness, the performance of the light brown color exceeded that of the other colors.

Table 1: Image quality changes with different reflective screen colors

Color / Item	Colorless	Light black	Medium black	Light brown	Dark brown
Image					
RGB	87/80/74	46/42/46	47/42/47	48/44/48	45/41/46
Contrast	68	78	79	79	80
Sharpness	78	141	138	164	152
Saturation	70	70	69	83	85

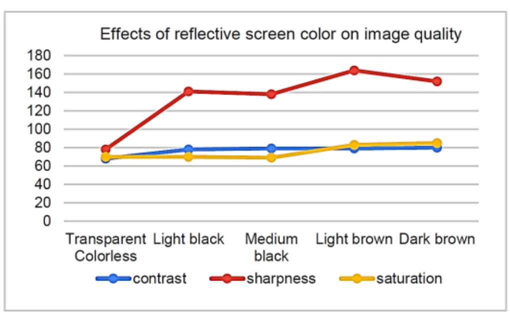


Fig. 8. Effects of reflective screen color on image quality

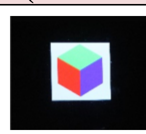
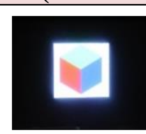
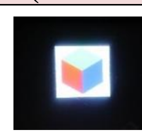
4.2. Influence of reflective screen film treatment

In addition to alternations in the material color of the reflective screen, a thin color film can be applied to the surface of the reflective screen. This section explores the effect of reflective screen film treatment on image quality. Various styles of glass films are available commercially. This study employed three types of commonly accessible glass films: light black film with a light transmittance of 35%, dark black film with a light transmittance of 5%, and dark silver film with a light transmittance of 10%. The effects of these films on image quality were analyzed and compared with that of a transparent colorless screen without film treatment. From Table 2, in terms of average RGB values, the results were similar to those obtained in the previous subsection regarding changes in reflective screen material color. The transparent colorless reflective screen without any film treatment exhibited a higher average RGB value, whereas the average RGB values of the three film treatments were approximately 50% lower in comparison with the transparent screen. Furthermore, the average RGB values for the three film treatments were similar. Therefore, regarding average RGB values, the performances of the reflective screen, based on its material color and film treatment applied, showed no distinct differences.

The three film treatments yielded similar contrast values. However, compared with the transparent filmless condition, all three film treatments had an increase of approximately 10 in contrast values. On the other hand, the differences in sharpness were more evident. The light black (transmittance 35%) and dark silver (transmittance 10%) films displayed a relatively greater improvement in sharpness, whereas the transparent filmless screen and the dark black (transmittance 5%) film exhibited comparatively lower sharpness.

All three film treatments had increased saturation values by approximately 12 to 24 compared with the transparent filmless condition. Reflective screens with higher transmittance after film treatment exhibited more satisfactory performance in all four image quality aspects. By contrast, films with excessively dark color and low transmittance did not demonstrate ideal results. Moreover, during direct visual observation of the images on the reflective screen, lower transmittance films projected glares around the images, as indicated in the second column of Table 2. The brighter glares around the images, from a viewer's perspective, did not contribute to a high-quality viewing experience. The light black film treatment with a transparency of 35%, however, showed the most satisfactory visual effect. Therefore, regarding film treatment of reflective screens, a thorough evaluation of the trade-off between image quality and visual experience is required. Image quality results under various film treatments are shown in the third column of Table 3. The effects of film treatment on image quality are illustrated in Fig. 9. Clearly, sharpness was the factor affected most by film treatment.

Table 2:. Effects of reflective screen film on image quality

Film / Item	Transparent colorless	Light black (35% trans.)	Dark black (5% trans.)	Silver (10% trans)
Image				
RGB	87/80/74	42/41/46	47/49/57	46/48/54
Contrast	68	78	79	78
Sharpness	78	142	70	181
Saturation	70	94	90	82

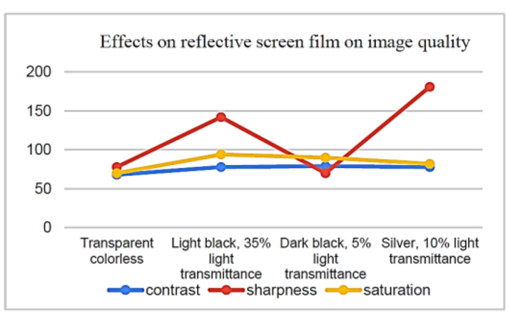


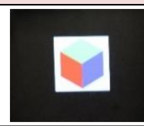
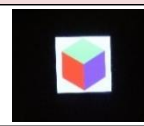
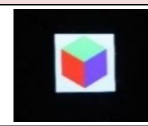
Fig. 9. Effects of reflective screen film on image quality

4.3. Image overlay on the reflective screen

When the light source of the projection screen reflects into the thin plate material of the reflective screen, repeated occurrence of refraction takes place because of the change in the light transmission rate between different mediums. Consequently, at the edges of the image, blurring and ghosting occurs (An, 2006). A close observation of the image edge conditions generated under different reflective screen thicknesses and combination conditions is shown in Table 3. Through the observation of the image edges, we discovered that when the reflective screen was composed of layered structures, the occurrence of ghosting increased, and the interference between the overlapped images became more pronounced. This led to more severe conditions of blurring and ghosting.

When the images projected by the reflective screen with tinted materials or film treatment were observed up close, a noticeable difference in the conditions at the image edges could be detected. With the presence of tints on the reflective screen, the blurring and ghosting conditions at the image edges were not noticeable. Therefore, the blurring and ghosting conditions at the image edges caused by a fully transparent reflective screen can be reduced by adding some color to the reflective screen material or by applying film treatment. The presence of color in the reflective screen material or the application of film treatment can decrease the occurrence of repeated reflections resulting from the penetration of light sources into the medium, thereby reducing blurring and ghosting. Thus, film treatment to improve overlay and blur situations at the edges of images is effective and obvious.

Table 3:. Comparison of image edge conditions resulting from different reflective screen combinations and film treatments

Thickness	Transparent colorless 2mm	Transparent 2 mm + 2mm	Screen color: light brown 2mm	Film treatment: light black (35% trans.)
Image				
Image edge				

5. Conclusions and suggestions

It is obvious from these experimental results that colorless transparent reflective screen materials are not the optimal choice for certain aspects of image quality, particularly in terms of edge blurring and ghosting. By contrast, a transparent reflective screen with a light brown tint had more satisfactory performance.

5.1. Conclusion

Regarding changes in the material color of the reflective screen, when the reflective screen material was changed from clear transparent to light black, medium black, light brown, and dark brown colors, the average RGB values decreased by approximately 50% compared with that produced on the colorless transparent screen. The differences in contrast and saturation values among the various material colors were not pronounced; however, a more noticeable variation in sharpness was observed.

Regarding film treatment on the reflective screen, black and brown film treatments led to a decrease in average RGB values. A potential reason for these decreases is the fact that the color of the reflective screen material or film treatment resulted in a darker base color. Consequently, when the average RGB values were calculated, the increase in the total grayscale quantity in the denominator yielded smaller values. The variations in contrast among different film treatments were not significant, with values only slightly increasing by approximately 10 compared with the transparent reflective screen. Nevertheless, a notable increase in sharpness was observed, particularly with the light black (35% transmittance) and dark silver (10% transmittance) film treatments. Furthermore, in terms of saturation, all three film treatments exhibited a slight increase in saturation values.

When observing images on a reflective screen made of a transparent colorless material, edge blurring and ghosting tended to worsen with increased thickness. However, with a slight tint of color in the material or through the application of a film treatment, a certain degree of improvement could be achieved in edge blurring and ghosting. The potential reason for this improvement is that when the reflective screen has color, the amount of penetrating light is reduced, which minimizes the occurrence of repeated reflections as the light passes through the film. Thus, film interference and refraction are mitigated.

Different from most of the existing research on holographic projection technology and application research, this paper presents quantitative changes in image quality of holographic projection obtained when adjusting material color and film treatment of the reflective screen. These numerical values provide a clearer understanding of the changes in image quality under the influence of these variables, which contributes to research on basic image analysis in holographic projection.

This study employs computational analysis through the OpenCV library to provide an objective form of image quality analysis distinct from subjective human judgments. This approach allows for the presentation of variations in image quality in the form of concrete quantifiable data. Furthermore, computational analysis enables a more precise revelation of the changes in holographic projection image quality under different variable conditions, facilitating more accurate analysis and judgment for image researchers. Ultimately, the presentation of these variations in image quality data can enhance performances of future holographic projection settings and provide viewers with a superior visual experience. This contribution of the study lies in its application of computational analysis to fundamental research in the field of holographic projection. The author's approach of integrating experimental and algorithmic analyses combines practical exhibition and computer applications, offering a scientific research model for future analysis and exploration of image quality. This model provides a feasible operational framework for image quality researchers.

5.2. Suggestions for future research

In this study on the effects of reflective screen material color and film treatment on image quality in single-sided holographic projections, the experimental conditions were relatively simple. In real-world settings, external environmental factors can vary greatly. The influence of environmental variables should be further studied. In addition, during the installation of holographic projection display facilities, adjustments to the ideal 45° angle of the reflective screen are often necessary because of spatial constraints or the need to expand the display area. These setup adjustments may affect imaging quality and should be explored in further research. Accordingly, we recommend future studies investigate the following aspects:

1. Effects of changes in the external environment (e.g., varying ambient illumination and color temperatures) on holographic image quality.
2. Effects on holographic projection image quality when the reflective screen is set at different angles than 45° to the projection screen.
3. Effects of background environment colors on holographic projection image quality.

As holographic projection becomes increasingly prevalent, gaining a more precise understanding of external environmental and internal equipment variables can contribute to the development and enhancement of related technology and the holographic projection industry. This study conducted an experiment to understand changes in image quality based on selected equipment variables. We anticipate that future research endeavors will continue to expand the foundational data available, which can improve the control of holographic projection image quality, contributing to the industry's future development.

Conflict of Interest

This study is developed and conducted by the author based on personal research and interests. It has not received any financial support or subsidies from external organizations or foundations. There are no issues related to conflicts of interest.

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