Scrolling Display That Visually Interpolates Pixel Gaps in Compact Aerial Display by Use of Retro-Reflector Slits

Daichi Tasaki1, Akinori Tsuji2, Toyotaro Tokimoto1,3, Shiro Suyama1, Hirotsugu Yamamoto1

hirotsugu@yamamotolab.science

1 Utsunomiya University, 7-1-2 Yoto, Utsunomiya, Tochigi 321-0904 Japan
2 Tokushima University, 2-1 Minamijosanjima, Tokushima, Tokushima 770-8501, Japan
3 XAiX, LLC, 5-3-1 Minatomirai, Nishi, Yokohama, Kanagawa 220-0012, Japan

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ABSTRACT

We propose that the scrolling display can visually interpolate the pixel gaps caused by retro-reflector slits mounted in front of a light source in compact aerial display configuration. The perceived quality of the aerial image with pixel gaps can be improved by scrolling display even when pixel gaps are increased.

1 Introduction

Compared to paper posters and conventional signboards, LED-based digital signage is used in train stations, banks, and stores because of its ability to switch display image. In recent years, the technology of displaying digital signage in the air has also become a hot topic.

Aerial imaging by retro-reflection (AIRR) [1] has been proposed for above applications. AIRR has a wide viewing angle and can be applied to a large aerial screen without special glasses. However, it requires a sufficiently large space for installation. In a previous study, an optical system [2] was proposed in which a retro-reflector with aperture and a beam splitter are placed in front of the LED panel, forming an aerial image in front of the LED panel through the aperture. This optical system for aerial imaging using retro-reflector with aperture reduces the space required for installation of the aerial display with AIRR.

However, there is a problem that pixel gaps by retro-reflector slits mounted in front of the light source in compact AIRR by using scrolling display. We conduct preliminary experiments to evaluate image quality and show the effectiveness of our optical design by use of retro-reflector slits.

2 Design of Aerial Display

2.1 Principles of AIRR and the Proposed Optical System

Figure 1 shows a diagram of the principle of AIRR, which is aerial imaging by retro-reflection. The reflected light is directed to the retro-reflector, the light incident on the retro-reflector is reflected in the same direction as the incident light, and the reflected light is transmitted to the beam splitter. The transmitted light forms an image in the air, forming an aerial image at the plane-symmetrical position of the light source with respect to the beam splitter.
2.2 Principle and Challenges of Compact Aerial Display Optics With Retro-Reflector Slits Mounted in Front of the Light Source

Figure 2 shows the principle of aerial imaging in an optical system with a retro-reflector slits mounted in front of the light source.

The retro-reflector processed in the shape of a vertical grid is installed on the surface of the LED panel that serves as the light source, and a beam splitter is placed in front of the retro-reflector to form an aerial image in front of the LED panel through the aperture, making the structure more compact than conventional aerial display with AIRR.

Light from pixels not covered by the retro-reflector enters the beam splitter and is divided into transmitted and reflected light. The reflected light is directed to the retro-reflector slits mounted in front of the LED panel, where the incident light is retroreflected in the same direction as the reflected light. The reflected light is again transmitted toward the beam splitter and forms a plane-symmetric image with respect to the beam splitter, resulting in the formation of a vertical slit-shaped aerial image.

The proposed optical system requires less space for installation compared to the conventional aerial display with AIRR, and we believe that this compact aerial imaging technology can be applied to a wide variety of situations. However, the problem is that some pixels gap due to the retro-reflector slits.

3 Scrolling Display Method

3.1 Occurrence of Pixel Gap by Retro-Reflector Slits

Figure 3 shows an image of a retro-reflector actually processed and mounted in front of an LED panel. The retro-reflector slits are placed at intervals of 2.5 mm to match the pixel pitch of the LED panel. Figure 4 shows an actual image of the string "A φ S" displayed on the LED panel. It can be seen that the pixel gap in the area where the retro-reflector slits is installed.
3.2 Realization of Scrolling Display by Switching Subframes at a High Speed

To solve the problem of pixel gap by installing retro-reflector slits, we propose a subjective super resolution method using scrolling. We prepare 64 subframes, in which the information of one pixel of the image is shifted from right to left one by one, in accordance with the pixels of the LED panel used as the light source. The scrolling display is realized by switching between these subframes at high-speed using a circuit implemented in an FPGA (Field-Programmable Gate Array).

Figure 6 shows a conceptual diagram of the scrolling display when a pixel gap every pixel interval.

4 Interpolation of Pixel Information in Non-Illuminated Areas by Subjective Super-Resolution of Scrolling

As the first step of a study to evaluate whether a subjective super resolution by scrolling is visible even when a retro-reflector slits mounted in front of an LED panel, we conducted an experiment to display a scrolling display in the air using a conventional AIRR. Figure 7 shows a part of the scrolling image in the air. The results of actual observation showed that even when non-illuminated pixels were generated at intervals of one pixel, the brain can perform pixel interpolation by scrolling through the non-illuminated pixels and the displayed images could be seen.
5 Experiments on Pixel Pitch Spacing of Light-Emitting Areas of LED panel

Figure 9 shows aerial images displayed with increasing pixel gaps. The wider the pixel gap from 2.5 mm to 27.5 mm, the more difficult it is to recognize the images at still image. When the pixel gap is between 2.5 mm and 7.5 mm, image shapes can be recognized. At the pixel gap of 10 mm, image groups are identified without precise shape recognition. Over the pixel gap of 15 mm, even image group is difficult to be identified.

On the other hand, scrolling these images with pixel gaps like Fig. 9 has a possibility to make it easier to recognize the image shape as shown in Fig. 8. As a preliminary experiment, the pixel gap was gradually increased in the scroll direction, and the perceived image quality of aerial images were estimated. As a result, even when pixel gaps are slightly increased, the image shape can be recognized. It is also suggested that the observer can perceive the image flow between left and right even when image shape cannot be recognized.

6 Conclusion

We propose that the scrolling display can visually interpolate the pixel gaps by retro-reflector slits mounted in front of the light source in compact aerial display.

Although the compact aerial display with AIRR has the pixel gaps which degrades the image resolution, our proposed scrolling display will provide visually interpolated image of higher resolution.

Preliminary experiments suggest that the image shape can be recognized even when the pixel gap is somewhat large, and that the left and right flow of the image can be identified even when the image shape cannot be recognized.

In the future, we intend to conduct experiments on human subjects to evaluate the interval at which they perceive that the displayed image is scrolling, depending on their viewing method, and to study an optical system in which the proposed retro-reflector slits are mounted in front of the light source.

References


