Glass-beads Display: Evaluation for aerial graphics rendered by retro-reflective particles

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Introduction

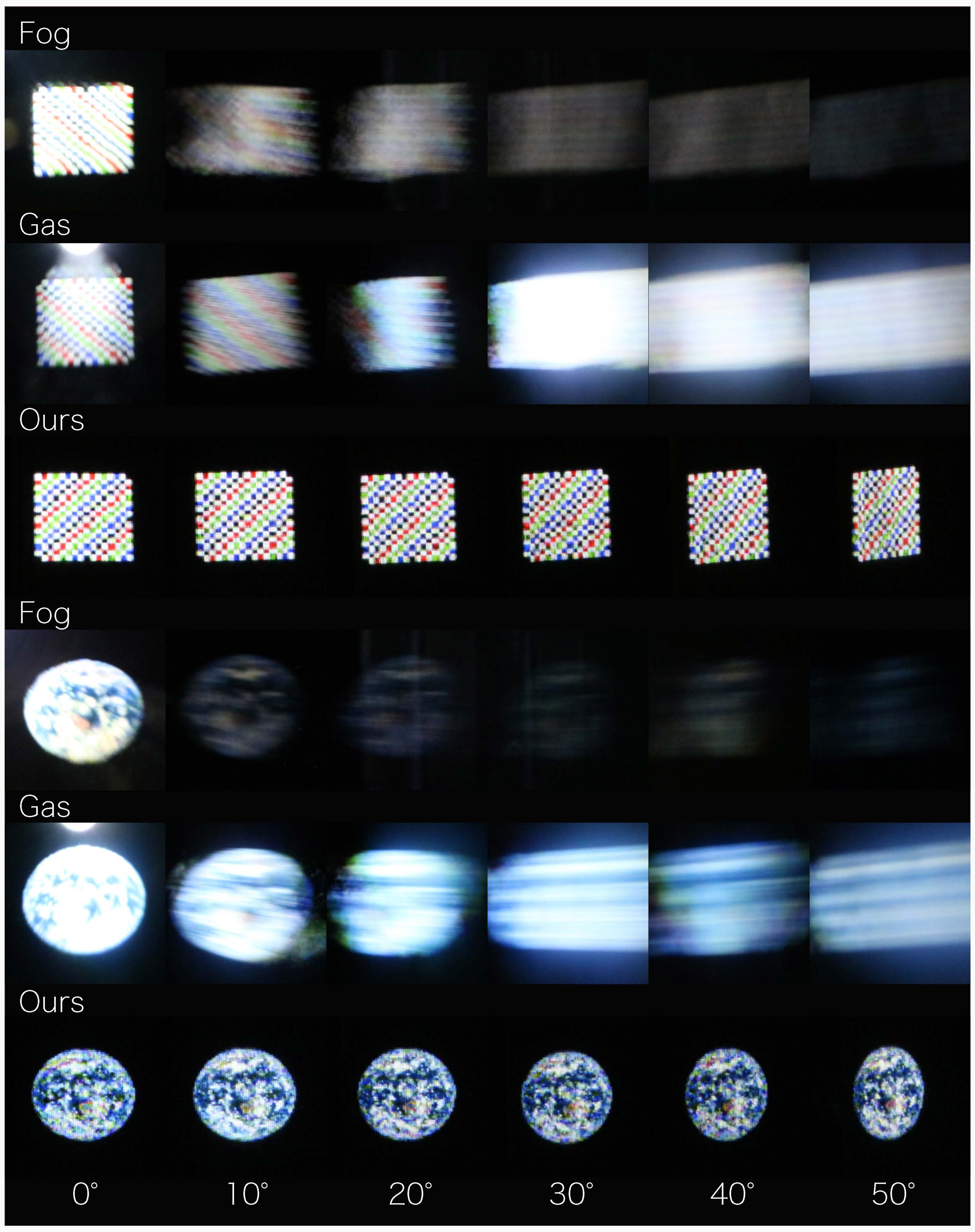
We propose a novel aerial imaging system using the retro-reflective particle screen. Retro-reflective particles are composed of glass beads that are half-coated with mirrors. They are commonly used in road signs to provide highlights in the dark.
We present an alternative application that uses glass beads as the aerial screen for augmented reality.
All aerial imaging systems have both positive and negative attributes; hence, we aim to contribute towards the study of aerial imaging systems by presenting a novel method for visualizing images in the air. In this paper, we quantitatively evaluate the characteristics of the proposed method. In addition, we conduct a comparative evaluation with existing aerial screens, such as fog and gushed displays. This paper is based on our previous study [1].

Experimental Evaluation

We installed the projector and the aerial screen at a distance of 70 cm. The short focus projector TH682ST (BENQ) is used for all sections of the experiment and user study. The display method was DLP, the resolution was Full HD (1920 1080), and the brightness was 3000 lm. The observer (e.g., human, camera, and luminance meter) is present/placed at a specific angle 100 cm away from the screen. We used three types of display for the aerial screen: glass-bead, fog, and gushed. Note that the position of the observer, the position of the projector, and the respective properties all remain the same. However, for the glass-bead display, a projector is placed between the observer and the screen. For the fog and gas displays, a screen is installed between the observer and the projector.

We captured photographs from each aerial screen (fog, gas, and glass-bead) at angles from 0 to 50 degrees, as shown in Fig. 3. All ISO were 6400, the F value was 8, and the shutter speed was 1 / 60. For all aerial screens, clear images were obtained from the front. However, as the angle increased the Mie scattering caused blurring on both the fog and gas screens.
Then, we captured the glass-beads screen from angles of 0 to 180 degrees, as shown in right figure. The proposed method obtained clear results irrespective of the viewing angle.

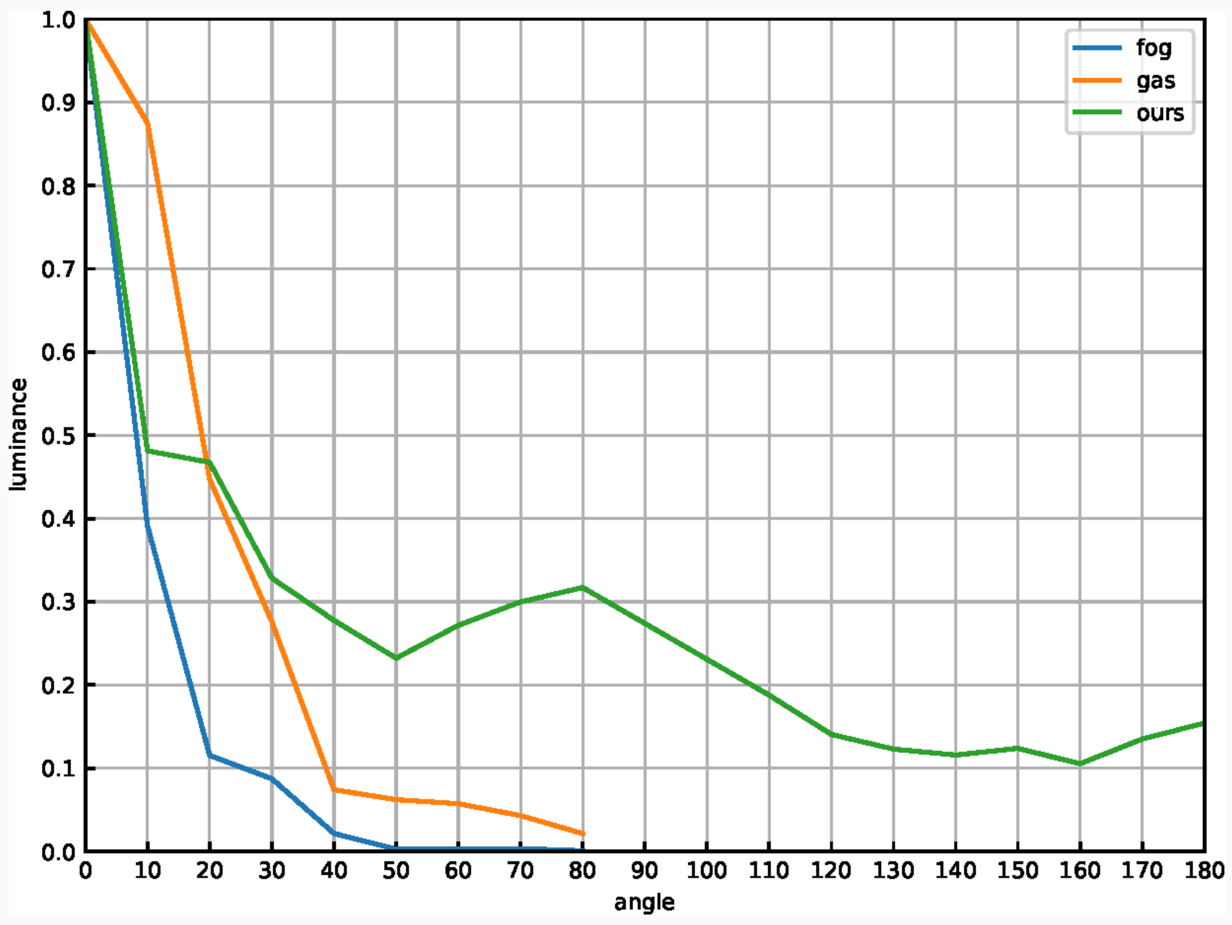
Fog Display A fog display was constructed to conduct comparative experiments. The hardware consists of an ultrasonic transducer, blower fan, blower PVC pipe, and 3D printed nozzle. The atomization capacity of the ultrasonic oscillator was 500 ml / h and the slit of the nozzle was 50mm 8mm.



Gushed Display We also prepared a gushed display for comparative experiments. To build the gushed display, we referred to the study by Suzuki et al. A cooling spray employed for cooling the human body in sports was adopted as a gas.

We measured the luminance with respect to the viewing angle for each display. We employed LS-160 (KONICA MINOLTA, INC.)4 as a luminance meter. All experiments were conducted in a dark room.

The luminance values in the case of center (i.e., 0°) was 89:93 cd.m2 for fog, 506:82 cd.m2 for gas, and 119:86 cd.m2 for ours. From the results, the gas screen possesses the highest brightness value. Glass beads possessed higher brightness values compared to the fog screens. Figure below shows the decrease in luminance versus angle.

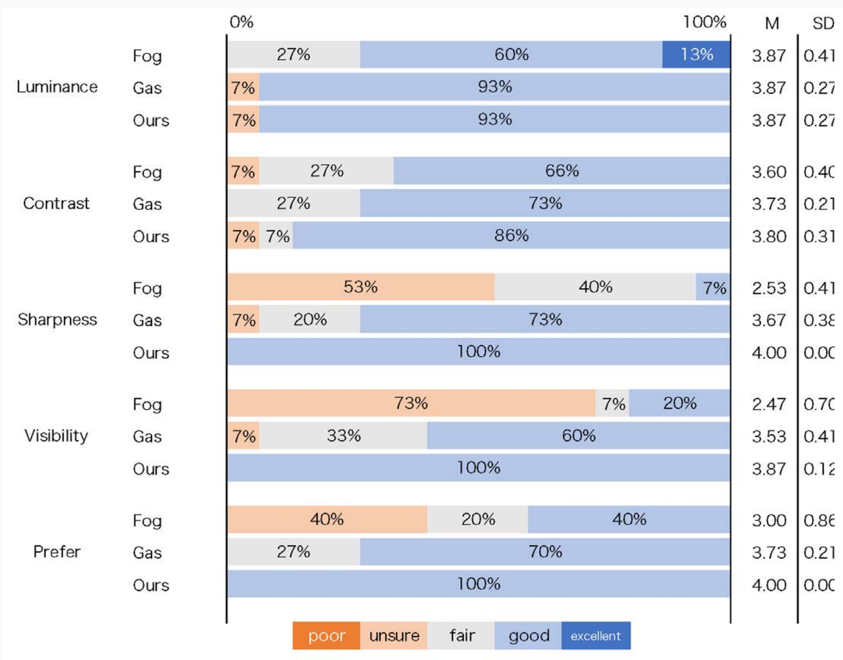


User Feedback

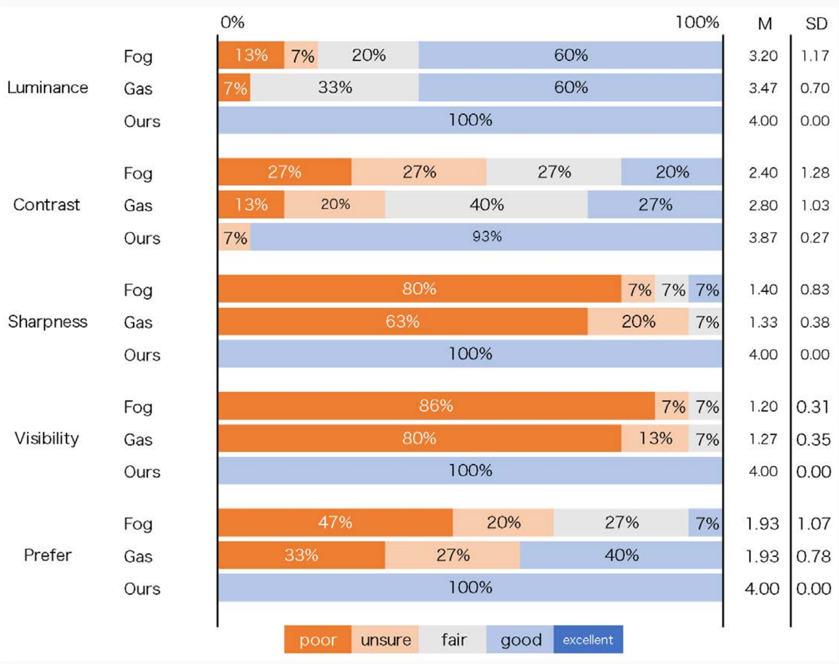
We conducted a user study with 15 participants (13 males and 2 females, with a mean age of 21 and a standard deviation (SD) of 3.43) for evaluating the performance of each aerial screen.

Three screens of fog, gas, and glass beads were arranged side by side, each with the configurations. We projected three images of earth, text, and a colored checker pattern on each screen. Participants observed the images from the front of each display. Each image (earth, text, and checker pattern) was displayed for approximately 5 seconds. Subsequently, the participants were asked to rate each screen on a scale of 1 to 5, where 1 = poor, 2 = unsure, 3 = fair, 4 = good, and 5 = excellent. The screen features being rated were as follows: Luminance, Contrast, Sharpness, Visibility, and Prefer.
After observing displays, the participants could re-observe another display and were able to update their ratings. After observing from the front, the experiment was conducted for observations from an oblique angle of 30 degrees using the same procedure.

The results of the questionnaire are shown in below figures. Our method recorded a higher average value than fog and gas screens despite the viewing angle (front or obliquely) for all the rated features.
When observed from the front, it was equivalent in luminance/contrast, but its sharpness/visibility was higher than both fog and gas. When observed from an angle, the contrast/sharpness/visibility of glass-beads screen was higher than both fog and gas. Moreover, its luminance did not change substantially, as compared to the other screens. Participants preferred our method in both the cases. Further, unlike fog and gas, our approach is robust against viewing angle.



0°



30°

Reference

[1]Ando, S., Otao, K., Takazawa, K., Tanemura, Y., Ochiai, Y.: Aerial image on retroreflective particles. In: SIGGRAPH Asia 2017 Posters. pp. 7:1–7:2. SA '17, ACM, New York, NY, USA (2017). https://doi.org/10.1145/3145690.3145730, http://doi.acm.org/10.1145/3145690.3145730

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