73.2: A Multi-View Projection Display

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Abstract
We describe a multi-view projection system. The system comprises multiple projectors and a screen with scattering angles that can be tailored to suit the viewing environments. The tailoring of the scattering angles is accomplished by incorporating micro-structures onto the screen surface. We have fabricated screens with horizontal scattering angles ranging from <1° to over 100° FWHM. We demonstrate a three-view display system with negligible crosstalk between the views. We also demonstrate a glasses-free 3D prototype with 20 projectors and a contiguous angular viewing zone of about 10°. The capability to tailor the screen scattering angle in conjunction with novel optics enables us to expand greatly the number of views of the displays.

1. Introduction
There is a growing demand for multi-view displays for use in applications such as HP's HALO Visual Collaboration Systems. High-quality multiple-view and glasses-free flat panels do exist already. But they are expensive and do not provide compelling viewing experience. Recently, Baker, Li & Martin [1] presented an elegant technique to capture and display many views using arrays of closely spaced inexpensive, low-resolution cameras and projectors. They use a screen consisting of a laminate of holographic diffusers and retro-reflectors to achieve a continuous 3D effect without viewing glasses. Accurate control of light diffusion by the holographic diffusers is difficult at small angles and thus the quality of the display is unsatisfactory. A robust and inexpensive screen technology that performs well for various display applications in conjunction with innovative optical configurations could help improve the quality of the display system greatly and thus usher in a much wider use of multi-view and glasses-free continuous-view 3D displays.

2. Methods and Results
We present techniques for multi-view projection systems. The techniques allow us to extend the number of views arbitrarily. We also present techniques that allow us to tailor the scattering angles of the screens to match the desired number of views.

We describe the techniques and the operation principles with the three-view projection display as depicted in Figure 1. The principles are equally applicable to an arbitrary number of views. The projectors illuminate the screen simultaneously from three equally spaced horizontal angular positions. A point on the screen reflects the illumination into a range of angular distribution, θ, in the horizontal direction. We will refer to θ as the horizontal scattering angle. Viewers would see only the images from one of the projectors if θ is smaller than the angular separation between adjacent projectors. The vertical scattering angle is engineered to be large enough to accommodate a comfortable range of viewing angles, ~>50° in our implementation. We can tailor the horizontal scattering angle from <<1° to well over 100°. This allows us to extend the number of views arbitrarily, limited only by the available physical space for the placement of the projectors.

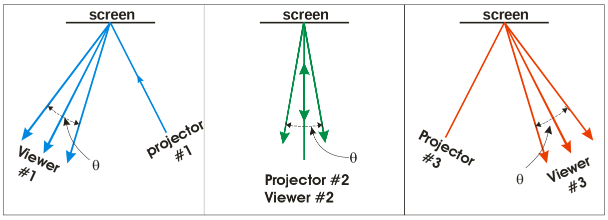

Figure 1. A three-view projection display. The viewers see images from only one of the projectors.

We use two types of screens to cover a wide range of scattering angles: brushed stainless-steel and a variety of HPLouver Screens with micro-structured surface [2,3.] Figure 2 shows the micro structures and the light scattering patterns of the brushed stainless-steel screen (A1) and two HPLouver screens (HP1, HP2 when the screen is illuminated at normal incidence with a collimated laser beam.

The measured full width at half maximum (FWHM) of the horizontal scattering angles are: ~<1° for screen A1, ~20° for HP1 and ~100° for HP2. Screen HP2 was tailored for single-view applications that require wide viewing angle and the results have been presented elsewhere [2, 3.]

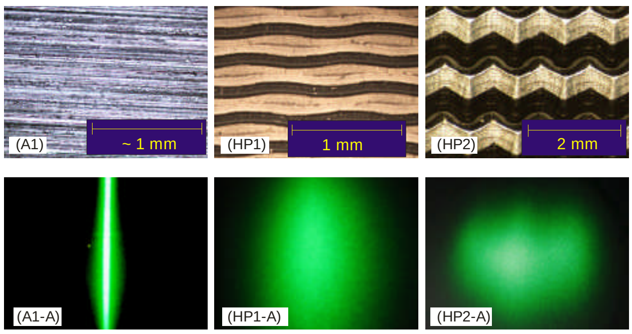

Figure 2. Micro structures of the several multi-view projection screens. A1: Brushed stainless-steel screen; HP1 & HP2: HPLouver Screen on Delrin®. A1-A, HP1-A and HP2-A depict the corresponding light scattering patterns.

We tested the multi-view characteristics of the brushed stainless-steel screen A1 and the HPLouver Screen HP1 in the three-projector setup depicted in Figure 1. The projectors illuminate simultaneously onto the same region of the screen with distinctive images at normal incidence and at incident angles of ± 45° respectively. The projected images superimpose on top of one another. We capture the images from the vintage points of the viewers #1, #2 and #3. Simultaneously, viewer #1 sees numeral "1" displayed on the screen, while viewer #2 sees "2" and viewer #3 sees "3" as shown in Figure 3. On the reference matte-white screen, the individual images are scrambled and barely discernable and the contrast is washed out.

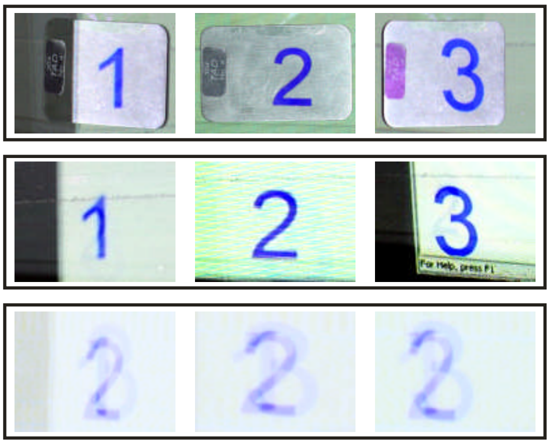

Figure 3. Images on our multi-view screens as seen by viewers at the three viewing positions depicted in Figure 1. Top row: Brushed-stainless-steel screen. Middle row: HP1 microstructure screen. Bottom row: Matte-white screen.

The three distinctive views with the brushed-stainless-steel screen and the HPLouver microstructure screen are clean, high-contrast, and with negligible crosstalk. For comparison, the images on the matte-white screen are completely scrambled and barely discernable as expected.

We have also developed technique to tailor the scattering angles of the screens. We are able to tailor the horizontal scattering angles ranging from nearly 0° to over 100°. A horizontal scattering angle of ~<1° is needed to achieve high-quality imagery for glasses-free continuous 3D (C3D) displays.

However, screens with small horizontal scattering angle have inherently limited viewing angles. In the multi-projector system with a flat screen shown in Figure 1, a viewer sees the imagery only on the portion of the screen that subtends an angle θ at the viewer. A viewer thus cannot see the complete imagery on screen from a single projector. This limitation is depicted further Figure 4A. Viewer #1 sees images from projector #2 only on a small portion on the left-hand side of the screen, while viewer #2 sees only images on the center section and viewer # 3 sees images on the right-hand-side portion of the screen. In a C3D system, a viewer sees only a sliver of the image from a single projector, as the scattering angle θ is reduced to <1°. The appearance of the image is similar to the scattering pattern depicted in Figure 2, panel A1-A. To allow a viewer to see images on the whole screen, we need an array of projector spanning twice the width of the screen and placed at approximately one-degree angular interval.

We use several techniques to alleviate this limitation and allow us to construct a glasses-free C3D system with only a limited number of projectors. Figure 4B depicts one of the techniques. The screen is curved into the shape of a cylinder. The projectors are placed along the circumference of another cylinder that intersects the screen. This is similar to the Rowland configuration used in X-ray crystallography. The cylindrical screen reflects the projector illumination toward a "conjugate" location on the projector placement circle. This allows an observer at the conjugate location to see the image on the whole screen from the corresponding projector. As shown in Figure 5, viewer #2 sees the image on the whole screen from projector #2 and viewer #3 sees the whole image from projector #3. We also use other techniques such as flat screens with integrated Fresnel lenses.

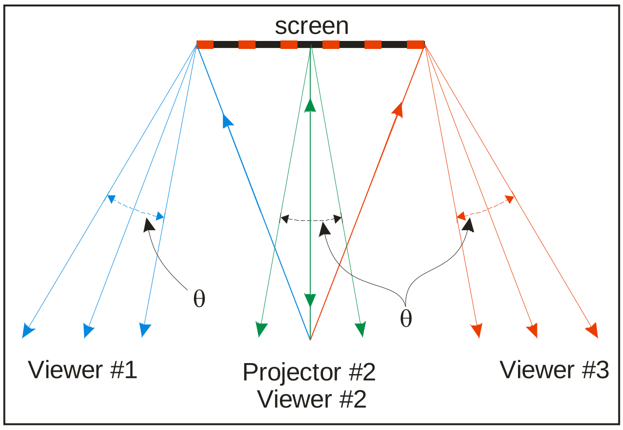

Figure 4. Projector #2 projects images onto a flat screen with a horizontal scattering angle θ. Viewers 1, 2 and 3 see images on different sections of the screen subtending an angle of ~θ at the respective viewer.

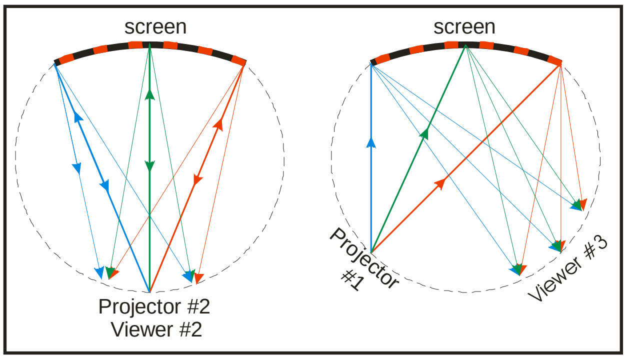

Figure 5. A curved screen converges the images on the whole screen toward the same viewing location.

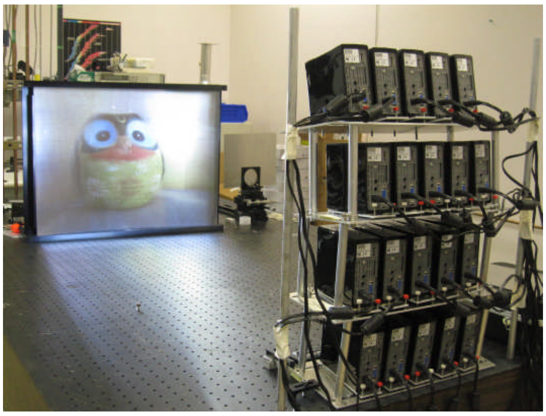

Figure 6. A prototype glasses-free continuous 3D display. We use 20 projectors spaced at an effective angular separation of 0.5°.

Figure 6 depicts a 20-view projection C3D prototype with the configuration shown in Figure 5. The prototype has a 30"-diagonal brushed stainless screen with an aspect ratio of 4:3. We use mini projectors M1 from AAXA with a brightness of 75 ANSI lumens. The projectors are placed at a spacing of 5-cm from one another and arranged in four tiers. The distance between the projectors and the screen is about 50”. The tier is successively offset by one-quarter of the center-to-center spacing of the neighboring projectors. This produces an effective angular spacing of ~0.5° between the projectors and thus a horizontal angular viewing zone of ~10°. The projectors project the image of a scene captured at an angular spacing also 0.5° apart. This allows us to demonstrate the principles and salient characteristics of glasses-free continuous 3D displays. We demonstrated with our prototype that throughout the contiguous viewing zone viewers see compelling 3D images naturally through binocular and motion parallax.

3. Conclusion

We have demonstrated a three-view display and a glasses-free C3D display using the multi-view techniques that we developed. We believe that multi-view display technologies will help enhance the functionality and user experience of many applications such as HP’s HALO Visual Teleconferencing Environment. We believe that the technical advances we achieve would be beneficial to the development of various implementation of glasses-free C3D displays [4,5,6]

4. Acknowledgements

Our thanks to Gil Perusa and Thiel Binau of the HP Labs model shop for fabricating the mounting fixtures for the projectors and screen.

5. References

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