Fragment Shadow : Generating Fragmented Shadows with Multi-Projectors Geometry and Color Calibration

Shunichi Kasahara
kasahara@csl.sony.co.jp
SonyCSL, University of Tokyo

Satoru Higa
satoruhiga@gmail.com
Backspace Productions Inc.

Akihiro Komori
komori@koozyt.com
Koozyt, Inc.

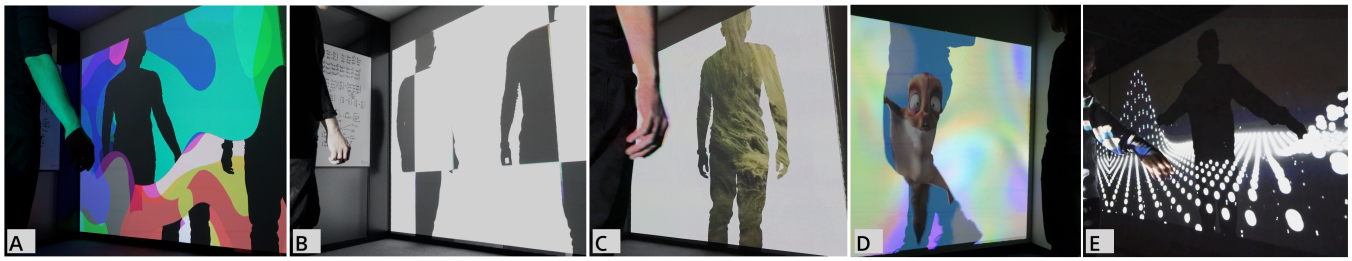

Figure 1: We demonstrate 'Fragment Shadow' a multi-projector system to generate visual transformed optical shadows. When our body occlude some of the multiple projectors, the shadow is visually transformed with various expressions, such as B) geometrically fragmented, C) a textured shadow in a uniform white, D) arbitrary moving video in a completely different texture and A, E) putting our shadows in between multiple layers of projection images.

ABSTRACT

We demonstrate Fragment Shadow a multi-projector system to generate visual transformed optical shadows without any latency. In our system, multiple projectors output different individual images onto the same surface to display one synthesized image. When the human body or objects occlude some of projectors, it reveals images from other projectors. Fragment Shadow enables the image synthesis pipeline in XYZ color space by the bi-directional conversion of RGB and XYZ color space and the correction of un-uniformity of projectors in addition to the geometry calibration between multiple projectors. Our optical shadow can be visually transformed with various expressions, such as geometrically fragments, textured shadow in the completely different visual and even putting our shadows in between the multiple layers of projection images. We envision the visual transformation of own optical shadow can provide unique sensations to our own bodies.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**.

KEYWORDS

Author Keywords: shadow; color calibration; projection mapping; virtual reality

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
SIGGRAPH '19 Studio, July 28 - August 01, 2019, Los Angeles, CA, USA
© 2019 Copyright held by the owner/author(s).
ACM ISBN 978-1-4503-6316-7/19/07.
https://doi.org/10.1145/3306306.3328003

ACM Reference Format:
Shunichi Kasahara, Satoru Higa, and Akihiro Komori. 2019. Fragment Shadow : Generating Fragmented Shadows with Multi-Projectors Geometry and Color Calibration. In *Proceedings of SIGGRAPH '19 Studio.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3306306.3328003

1 INTRODUCTION

The shadow is the most primitive graphic that projects ourselves, and the transformation of own shadow induces the changes of our own body sensation. There have been many prior work which uses the metaphors of own shadow changes, however, in many cases, shadows have been generated by capturing human body through cameras or depth sensors, which have several limitations in the resolution of the shadow and the synchronization between the shadow and own body. We believe the visual transformation of own optical shadow without any latency will provides unique experience in own body sensation.

Therefore, we introduce a multi-projector system called 'Fragment Shadow' which allows us to generate visual transformed optical shadows. In this system, multiple projectors output different individual images onto the same projection surface at the same time, and the physical rendered image on the surface is controlled by synthesizing individual output images. When the human body or objects enter the projection space, the occlusion of one projector reveals images from other projectors. Then Fragment Shadow enables generating arbitrary visual expression in the optical shadow.

As a remarkable prior work of our approach, Movie-in-Shadow [Minomo et al., 2006] (Textued Shadow [Kato et al., 2003]) by Yugo et al. realized to generate a plane white image on the projected surface from two projectors by generating the look up table of the complement color for white color. However, there were restrictions on the final output color and the number of executable projectors.

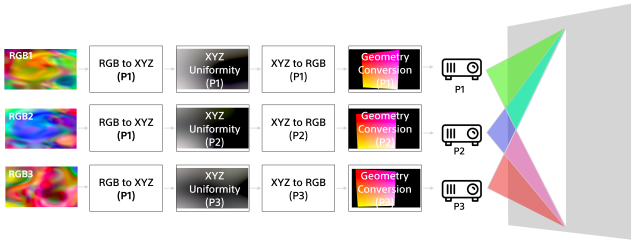

Figure 2: Principle image processing pipeline in Fragment Shadow. With the bidirectional conversion between RGB - XYZ and the uniformity calibration in XYZ color space, the system can perform mask, addition and subtraction operation of color on the projection plane.

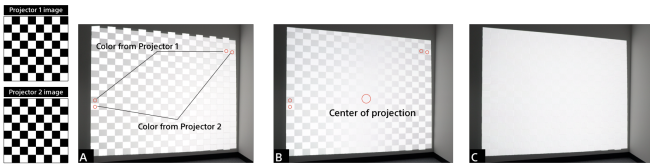

Figure 3: Process of the color calibration and the uniformity calibration. Here, two projectors output a white-black checker board image which are complimentary each other. A: original capture before any correction. B : after color calibration but without the uniformity correction, and C: color and uniformity are both corrected after calibrations.

Fragment Shadow enables the image synthesis pipeline in XYZ color space by the bi-directional conversion of RGB and XYZ color space and the correction of internal un-uniformity each projectors, as well as the pixel order geometry calibration with the structured light scanning and the frame synchronization of multiple projectors. Then Fragment Shadow enables generating various visual expression in the optical shadow with multiple projectors.

2 FRAGMENT SHADOW SYSTEM

Fragment Shadow system hardware consists multiple (up to 8) projectors (BenQ, W2000 DLP projector), 4K Camera, a Computer with GPU (Nvidia quadro p4000), HDMI-SDI convert (AJA HA5-4K) and Spectroradiometer(SR-UL2). Fragment Shadow consists of four technical components: Geometry Calibration, Color Calibration, Uniformity Calibration and Frame synchronization (Fig. 2). Here in particular, the color calibration and uniformity calibration will be described.

2.1 Color calibration

The system performs the color calibration using RGB-XYZ conversion to enable color synthesis regardless of the individual differences of each projectors. We used the spectroradiometer (SR-UL2 [1]) to measure the XYZ value when outputting with the interval pixel value in each R, G, B channels. When we denote $X_R = a_{RX}R^g + b_{RX}$ as X value when displaying R channel color only, the conversion RGB to X is described as $X_{(R,G,B)} = X_R + X_G + X_B$. With measured XYZ data, the system estimate all parameters for the conversion (R, G, B) to (X, Y, Z). Then the system also calculate the inverse conversion (X, Y, Z) to (R, G, B) as $RGB_{(X,Y,Z)} = (A^{-1}[XYZ - B])^{-g}$, here A and B is the matrix representation of series of a and$b$ parameters for all combination of R, G, B and X, Y, Z. With this calibration process, RGB and XYZ can be bidirectionally exchangeable in the measured projector. Note that this calibration is only valid for the center of the projector where we measure with the spectroradiometer (Fig. 3-B).

[1]https://www.topcon-techno.co.jp/en/products/sr/sr-ul2.html

2.2 Uniformity Calibration

To calibrate the uniformity, the system perform the projector-camera uniformity calibration with the parameter fixed camera device. After projecting the gray image from the projector, the system shifts the gray RGB so that the entire projection area gets uniform with RGB value of the center portion, then Uniformity Gray texture $G_{RGB}(u, v)$ can be obtained. Here, we define Homogenization texture as $H_{XYZ}(u, v) = (G_{XYZ}(u, v) - G_{XYZ}(0.5, 0.5))/G_{XYZ}(0.5, 0.5)$, note that $G_{XYZ}(u, v)$ is calculated with the RGB-XYZ conversion. By calculating the following conversion with this Homogenization texture, the uniformity of the projector output can be greatly improved in realtime (Fig.3-C).

$$I'_{XYZ}(u, v) = I_{XYZ}(u, v) + H_{XYZ}(u, v)I_{XYZ}(u, v)$$

By performing these calibration processes for each projector, it is possible to synthesize images in common XYZ space, even with more than three projectors.

2.3 Fragment Shadow pipeline

Figure 2 shows the principle image processing pipeline in Fragment Shadow. Fragment Shadow pipeline enables addition and subtraction operation of color on the projection plane. For example, it is possible to synthesize a uniform white plane (Fig. 1-C) or even arbitrary moving images from a completely different texture (Fig. 1-D) which we can see when we occlude one of them. As other remarkable expressions, it is possible to put our shadow in between the multiple layers of projection images (Fig. 1-E), or even generate geometrically fragmented shadows from own body (Fig. 1-A, B).

3 CONCLUSIONS

Fragment Shadow system makes it possible to transform our own shadows, which originally monochrome into the optical shadow with various movements and textures, fragmentation of shape and visual effects that the shadow exists within the projected image. We envision that with this visual transformation of own optical shadow, Fragment Shadow can provide unique sensations to own body which the shadow belongs to.

REFERENCES

H. Kato, T. Naemura, and H. Harashima. Textured shadow. In *Proceedings of the 2Nd IEEE/ACM International Symposium on Mixed and Augmented Reality*, ISMAR '03, pages 352–, Washington, DC, USA, 2003. IEEE Computer Society. ISBN 0-7695-2006-5. URL http://dl.acm.org/citation.cfm?id=946248.946829.

Y. Minomo, Y. Kakehi, M. Iida, and T. Naemura. Transforming your shadow into colorful visual media: Multiprojection of complementary colors. *Comput. Entertain.*, 4(3), July 2006. ISSN 1544-3574. doi: 10.1145/1146816.1146832. URL http://doi.acm.org/10.1145/1146816.1146832.