Kirameki Display: Practical Light Field Display to Represent Real Texture

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ABSTRACT

We have developed "Kirameki display" that can represent real texture of materials. In addition, we have built Unity Kirameki plugin that enable us to generate a real-time and interactive "texture representation" video with 60Hz frame rate with 4K display. Finally, we discuss more advanced technologies for texture representation.

1 Introduction

Recently, it is considered that light field display technology is one of the most feasible technologies to satisfy all visual perception of human because the light field display has 4 important features; 1) binocular stereopsis, 2) motion parallax, 3) eye accommodation and 4) texture representation[1][2]. Therefore, a lot of studies have been made to improve the display performance and to validate its visual perception. However, the light field display has still not been accepted widely on the world market due to several drawbacks like space resolution reduction, image blurring in the depth direction, moiré, narrow viewing angle and high cost of image rendering.

On the other hand, the technology of realistic texture presentation of materials on computer graphic (CG) model and the capturing / estimating the texture of materials on real objects become more hot and popular in the industry of movie film, advertisement and amusement. We can enjoy it even on a tablet device or a smartphone. However, this texture representation on the market is not "true" texture representation with light fields that include the reflective / transmissive light profile of materials in angles.

Our goal of this study is to develop the practical light field display that is specialized for texture representation without any drawback and to propose its total system for commercial usages. We are going to propose CG based video system and finally discuss about how to achieve real image based video system and also further texture representation topics in future.

2 Principle and Design

We have developed Kirameki display system where "Kirameki" means shining / glitter sense in Japanese. Figure 1 shows a principle of texture representation with light fields on Kirameki display. Normal display cannot show any difference of light intensity and color in angle (Fig. 1(a)). On the other hand, light field display can reproduce an angular profile of the light reflection based on material properties and light sources that is called "surface light field[3]" (Fig. 1(b)). Then we perceive the difference of light intensity and color from binocular vision and motion of head, body or hand (if we hold the display device in hand) and it gives us an additional sense of texture.

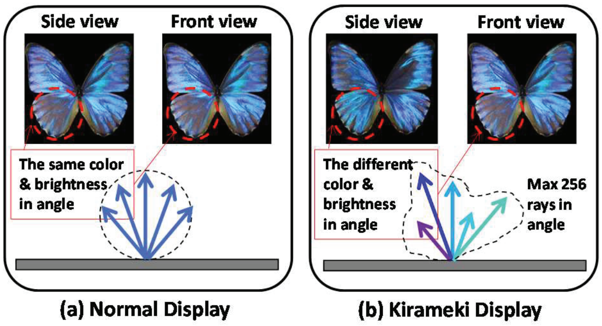


Fig. 1 The principle of Kirameki display

2.1 Kirameki display

We have designed 17.3inch and 28inch Kirameki display with 3840 RGB x 2160 IPS LCD panel and optical lens layer on top of the LCD panel. Table 1 shows a basic specification of the Kirameki display. As our goal is practical display for commercial usages, we have designed moiré free by the optical simulation of the pitch and angle of the optical lens and pixels and also sufficient space resolution (around full HD) and high angular resolution to reproduce the light rays with at least one degree angular step. It has been achieved by Innolux digital sub-pixel rendering of N3D technology[4].

Table 1 The specification of Kirameki display

Display type	LCD (IPS mode)
Display size	17.3inch / 28inch
Input resolution	3840 RGB x 2160
Output resolution	around full HD
Angular resolution	31 ~ 256 (max)
moiré	free

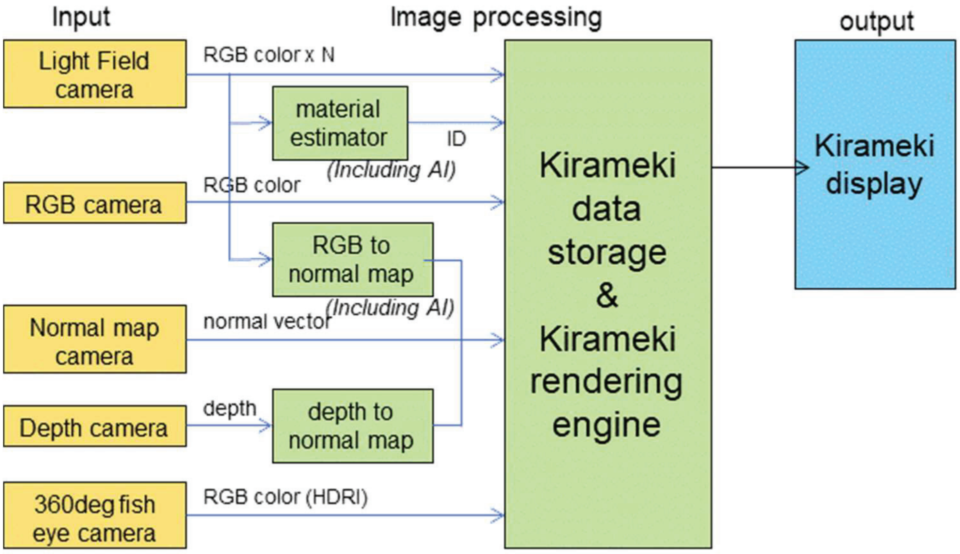


Fig. 2 The diagram of overall Kirameki display system

2.2 Basic Kirameki image rendering

Figure 2 shows a diagram of overall Kirameki display system. Based on this diagram, we have studied several input devices or parameters and its image rendering method. For Kirameki CG generation, the input parameters for the system are shown in Fig. 3. Basically we need a) base color, b) material ID and a corresponding properties of the material like bidirectional reflectance distribution function (BRDF) and c) normal vector map of the sampling point. Then we can process images by the physical based rendering (PBR) with Cook-Torrance model[5]. The difference in the Kirameki image rendering is that view vectors of the PBR are not fixed to the direction to the camera position. They are directed to views of the light field respectively. For Kirameki real photo generation, the best way is to capture the surface light field of all objects directly by using a light field camera. However, it requires high cost for capturing. In another way, capturing video that includes texture information (normal map and material information) is still challenging for us. It will be discussed in the chapter 4. And please notice we don't reproduce "depth" sense even though we use light field display. Because it brings us several drawbacks we mentioned in the Introduction section.

a) Base color b) Material ID c) Normal map

Fig. 3 Input parameters for Kirameki CG generation (We used the CG model "Tune-chan" of the G-Tune official character.)

2.3 Advanced Kirameki image rendering

The basic PBR can be applied for usual materials like metal, plastic and glass. However, it cannot be applied for the structured color like rainbow hologram on a toy card or the special surface treatment of a smartphone body. We studied this advanced Kirameki image rendering too. The input parameters are 1) diffraction pitch, 2) diffraction angle and 3) opacity (= alpha value) of the sampling point for the diffraction grating simulation. It can be allocated to R, G and B value of the texture map of 3D object or the texture layer of 2D image. Fig. 4 shows the example of the input pattern of rainbow hologram.

2.4 Kirameki display system

For Kirameki CG generation, we usually use Photoshop and Blender to make input image source like texture maps and 3D models, and Visual C++ and Unity 3D (URP mode) for the image rendering. We selected Unity because it is one of the most popular development tools for game, AR, VR and other interactive software applications. Additionally, Unity can generate the multi-platform application that include Windows, iOS, Android and iPadOS. At first, we selected Windows 10 for the development platform. For Kirameki photo generation, we made the Kirameki photo capturing system and the photo converter by Visual C++ and OpenCV. It re-allocates the light rays from sequential photos to proper direction that is defined by the geometry optics on the Kirameki display.

3 Implementations and Results

Figure 5 demonstrates our 28inch Kirameki display with the real photo of a saxophone. We can feel a strong shining sense of the saxophone's metal body from around full HD resolution and 61 light rays in angle. From our experiments, the high space resolution is significant for the detail texture feeling like scratch of the metal and the high density light rays must be represented by at least one degree step if the surface of the material is smooth like a mirror. In general, the naked eye type light field display has the limited viewing zone that is defined by the optical design. However, Kirameki display has no critical limitation of viewing zone because the repeating angular profile of reflection usually happen in ordinary office room and shopping facilities.

3.1 Unity Kirameki plugin (Basic)

We have developed a Unity plugin for both 3D material and 2D material. We have applied the 3D material to the glossy texture of SSU Unity-chan's cloth, hair and skin by drag and drop action and slider control of adjustment of PBR parameters (Fig. 6). The 4K demo video is rendered by CPU, not GPU in real-time speed (60Hz). We can feel shiny or glossy texture on the 3D model in real-time. The plugin for 2D material can be applied for the simple effects like a foil printing effect and an aurora effect on the logo or the background of image contents. We have also confirmed the function and GUI of the Unity plugin is acceptable for game or amusement software creators.

3.2 Unity Kirameki plugin (advanced)

We have also developed a Kirameki plugin for rainbow hologram effects based on diffraction grating pattern. We have tried several patterns that are typically used on toy cards. At first, we analyze toy cards to measure diffraction grating patterns (pitch and angle of slit and space). Then the parameters are converted to RGB texture map. For example, a) tiled square, b) heart, c) sparkle and d) crystal pattern are represented on the screen (Fig. 7). The diffraction pitch is set to close to the wavelength of visible

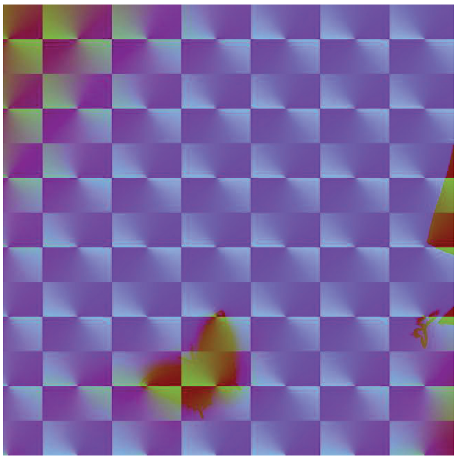
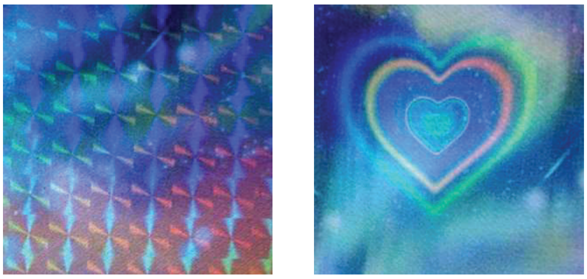


Fig. 4 Input pattern of rainbow hologram

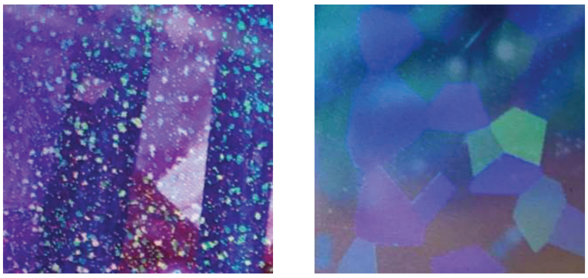
Fig. 5 28inch Kirameki display (photo: saxophone)

a) Original b) Kirameki material

Fig.6 Unity Kirameki plugin demo: SSU Unity-chan (© Unity Technologies Japan / UCL)



a) Tiled square b) Heart



c) Sparkle d) Crystal

Fig. 7 Rainbow hologram patterns (4 photos) light (e.g. 500~1,000nm) to represent strong color changing in angle. They look very attractive effects for game application because it gives players premium sense. Moreover we can show its animation and an overwrapped image of two different hologram patterns that are difficult in usual printing type hologram on a paper.

4 Discussion

We have developed the light field display that specialized for texture representation. It doesn't show any drawback like image blurring in the depth direction, moiré, narrow viewing angle and high cost of image rendering. Therefore we hope it can be widely applied for the commercial usages. Even so, there are some critical image contents. For example, jewelry needs to show very high contrast of specular light reflection in angle and small shining objects require higher density of total light rays in space and direction. Also high dynamic range (HDR) technology is preferred to represent shining objects more effectively in future.

Next we have developed Unity Kirameki plugins with real-time CG generation and the Kirameki photo converter for real photos with texture representation. However, we have only proposed the basic tools for the initial evaluation for commercial usages. If we want to reproduce more realistic texture like skin or another kind of structured color, we need to develop subsurface scattering (SSS) algorithm or thin film interference algorithm with surface light field control. Also we still have some difficulties to capture a real video. The current image capturing method that requires sequential shots for one frame is not suitable for video recording. We should develop a new surface light field camera or texture / material estimation algorithm with neural network in future. We think the relighting technology[6] is one of the candidates for this work. And for real-time transmission or storing video contents, we must develop an effective video encoder and decoder that can compress and decompress the angular light profile for pixels.

5 Conclusions

We have developed 1) Kirameki display, 2) Kirameki photo capturing system and its converter, 3) Unity Basic Kirameki plugin and 4) Unity Advanced Kirameki plugin for several image / video contents generation with real texture feeling. The obtained image performance seems to be attractive and practical enough for some commercial application. We hope this display technology will be combined with new camera and image processing technologies well and used for a lot of new applications in future.

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References

[1] Y. Takaki and T. Dairiki, "72-directional display having VGA resolution for high-appearance image generation", Proc. SPIE, vol. 6055, 60550X-1-8 (2006).
[2] T. Koike, "BRDF display: Interactive View Dependent Texture Display using Integral Photography", ACM SIGGRAPH 2008, USA(2008).
[3] D.I. Azuma, "Interactive rendering of surface light field", Technical Report UW-CSE-2000-04-01 (2000).
[4] Chin-Yung Hsieh, Hao-Yu Liu, Ruey-Jer Weng, Wei-Yi Lu, Naoki Sumi, "Ultra high resolution and VAC-free N3D technology and its applications", LDC2021 (2021).
[5] R. L. Cook and K. E. Torrance, "A Reflection Model for Computer Graphics", Comput. Gr., Vol. 15, pp. 307-315 (1981).
[6] R. Pandey, S. O. Escolano, C. Legendre, C. Hane, S. Bouaziz, C. Rhemann, P. Debevec, and S. Fanello, "Total Relighting: Learning to Relight Portraits for Background Replacement", ACM SIGGRAPH 2021(2021).