Viewing Angle Enhanced Point Light Source Display using Additional Light Sources

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Abstract: A Viewing angle (VA) of Point Light Source (PLS) display, which is one type of Integral Imaging (InIm) display, is low. We proposed to enhance a VA of PLS Display. The new method used nine additional light sources to increase the VA 2.83 times larger than a conventional method along horizontal and vertical directions. These additional light sources will increase the angle of the ray that gathered by the elemental lens. From the experimental results, the VA of the proposed method is 2.55 times larger than the conventional method.

1 INTRODUCTION

InIm Display is full parallax, full color, natural depth, and independent of the viewer (B. Lee, 2006). However, InIm has disadvantages such as short depth range, narrow viewing angle, and low resolution (J.-H. Park, 2001), (J.-H. Park, 2005), (S. -W. Min, 2003).

Three-dimensional (3-D) display images and 3D view by certain states that angle expressed in terms of the angle of the range. PLS display determined using conventional viewing angle is very small.

The previous methods to enhance the VA used time-multiplexed method (D. -H. Shin, 2006) and dynamic barrier array (H. Choi, 2003). Those methods enhanced only horizontal VA and required different elemental images.

In this paper, we will face according to each section: the 2nd section is viewing angle of the conventional point light source display, the 3rd section is a new method to determine the point light source display enhancement viewing angle measures, the 4th section is experiment and discussion, the 5th section is conclusions.

2 VIEWING ANGLE OF CONVENTIONAL POINT LIGHT SOURCE DISPLAY

The structure of conventional PLS display is shown in Fig. 1. A light source is at the focal point of the collimating lens. The elemental lenses collect parallel rays at the focal points so each elemental lens creates one PLS. Therefore, it is called PLS array.

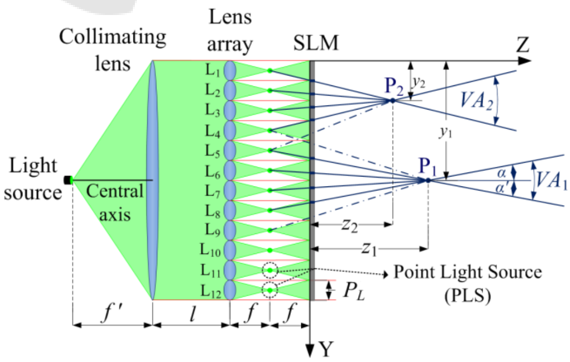

Figure 1: Structure of PLS displays and estimate its viewing angle.

Rays from PLSs are modulated transmission-type spatial light modulator (SLM), which is located behind the lens array, according to an elemental

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image. Figure 1 illustrates how to create two integral points. Their y_1, y_2 are a distance of along Y axis. Their z_1, z_2 are a distance of the integrated points P_1 and P_2 from the SLM display. The two integrated point P_1 and P_2 appear at the cross section of 4 rays, but VAs of those two points are not equal. However, the maximum VA of the conventional PLS display is given by:

$$VA_C = 2\cdot\arctan\left(\frac{P_L}{2\cdot f}\right). \tag{1}$$

where P_L is a pitch and f is focal length of the Elemental lens.

The P_1 appears at the cross section of 4 rays. Two dot-dash lines are not used to create integrated point P_1 because those two lines are outside diverging angle of elemental lens L_4 and L_9, respectively. The P_2 appears at the cross section of 4 rays. A dot-dash line is not used to create integrated point P_2 because this one line is outside diverging angle of elemental lens L_5 respectively.

From the Fig. 1, we can see that the VAs of P_2 and P_1 differ and VA_2 is greater than VA_1. Therefore, the VAs of the integrated points are not the same and depend on the positions of the integrated point. The VA_1 of P_1 is the sum of α' and α. The VA_1 is given by:

$$VA_1 = \arctan\left(\frac{y-(j-0.5)\cdot P_L}{z+f}\right)+\arctan\left(\frac{(j'-0.5)\cdot P_L-y}{z+f}\right). \tag{2}$$

where z is the distance according to z-axis, y is the distance according to y-axis, and j and j' are the elemental lens index.

We can conclude that VA of integrated point increases if the diverging angle of PLS increases.

3 NEW METHOD TO DETERMINE THE POINT LIGHT SOURCE DISPLAY ENHANCEMENT VIEWING ANGLE MEASURES

We used additional light sources (LS_2, LS_3) to increase the diverging angle of PLS. Figure 2 shows a structure of the proposed method. The three light sources are on the focal plane of a collimating lens and different lateral positions, so light rays of those 3 sources propagate to three different directions.

Those rays are collected by three neighbouring elemental lenses at the focal point of the center elemental lens when a distance between two light sources is equal to $s=f'\cdot P_L/f$, where P_L is a size of the elemental lens, f' is a focal length of a collimating lens, f is a focal length of the lens array.

In other word, one elemental lens collects light rays from the three different sources at the three positions, as shown in Fig. 2. Hence, one PLS consists of three parts of up, center, and down illuminations.

The two additional parts of PLS enhance the diverging angle of PLS so VA of the proposed method is enhanced.

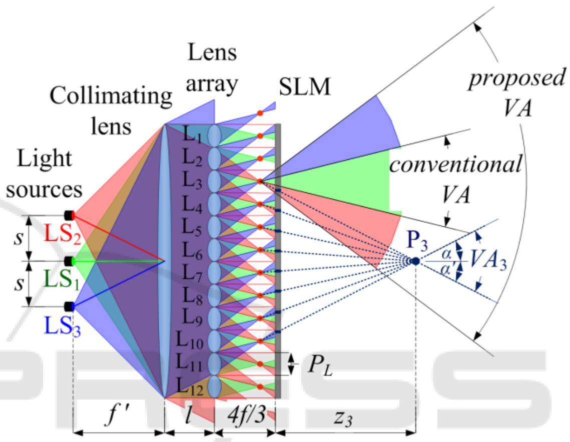

Figure 2: Geometrical structure of new method.

From the Fig. 2, we can determine the VA of proposed method:

$$VA_P = 2\cdot\arctan\left(\frac{3\cdot P_L}{2\cdot f}\right). \tag{3}$$

According to Eq. (1) and Eq. (3), the VA of proposed method is larger than the conventional method.

$$VA_3 = \arctan\left(\frac{y-(j-0.5)\cdot P_L}{z+\frac{f}{3}}\right)+\arctan\left(\frac{(j'-0.5)\cdot P_L-y}{z+\frac{f}{3}}\right). \tag{4}$$

We can find angles of each integrated point of PLS display Eq. (4). In other words, we can define VAs of all the integrated point.

4 RESULTS AND DISCUSSION

4.1 Simulation and Discussion

When a focal length of an elemental lens is 3.3 mm and a pitch of elemental lens is 1 mm, the VA of the conventional method is 17.2°, according to Eq. (1).

In the same configuration, the VA of proposed method is 48.8°, according to Eq. (3). It is almost 2.83 times larger than conventional method theoretically.

Table 1: Parameters of simulation.

Specification	Characteristic
Lens array	30 (H) × 30 (V)
Elemental lens dimension	1 mm (H) × 1 mm (V)
Focal length of lens array	3.3 mm
Distance between lens array and SLM new method	4.4 mm

Parameters of the simulation are listed in Table 1. In the simulation, the distance of the integrated point is 0-60 mm along the z-axis and 0-30 mm along the y-axis.

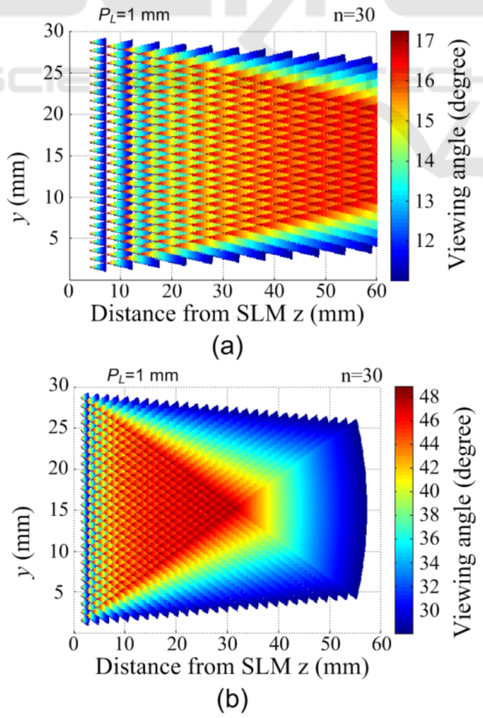

Figure 3: Calculation of the VA. (a) a conventional method and (b) a new method.

However, PLS is volumetric display, we calculate the viewing angle on the x=0 yz planes. PLS is the symmetric display so results on y=0 xz plane are same as x=0 yz planes.

In Fig. 2, we draw just three light sources, but we used nine light sources (LS_1, LS_2 ... LS_9 are shown in Fig. 6) in simulation to enhance VA along the horizontal and vertical axis. In the simulation, we calculated the VAs of 180,000 (300×600) integrated points in both configurations, as shown Fig. 3. The viewing angles of integrated points at the same distance from the SLM have small variation, from the simulation results. In Fig. 3(a), the maximum VA of the conventional method is 17.2°, according to Eq. (2). In Fig. 3(b), the maximum VA of the new method is 48.8°, according to Eq. (4).

We created two sets of elemental images for the conventional PLS display and a new method, as shown in Fig. 4.

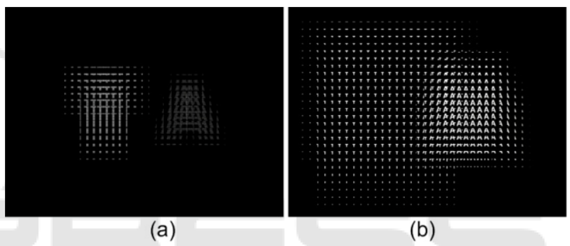

Figure 4: Elemental images (a) for PLS display and (b) new method.

The number of elemental images for the new method is larger than a conventional display. The additional elemental images of new method enhance VA because the large diverging angle requires additional elemental images.

4.2 Experiment and Discussion

The experimental setup is shown in Fig. 6. In the experiment, we used 1 mm lens array. The specification of the lens array is given in Table 1.

Therefore, in the experiment, we only used the two InIms that are discussed in the simulation. In each experiment, we took pictures after we changed the position of the camera and then rotated the camera when it was within the boundary between the viewing regions of the InIm.

The camera is similar to a viewer, so the angle of the camera is the VA of the integrated point. In the experiment, we used two objects. Distances of objects, “A” and “T”, are 10 mm and 20 mm from the lens array, respectably, as shown in Fig. 5.

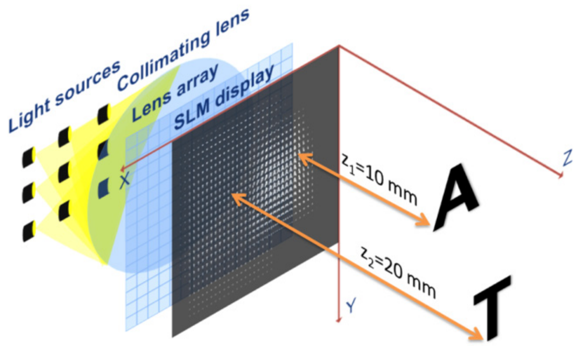

Figure 5: Experimental configuration.

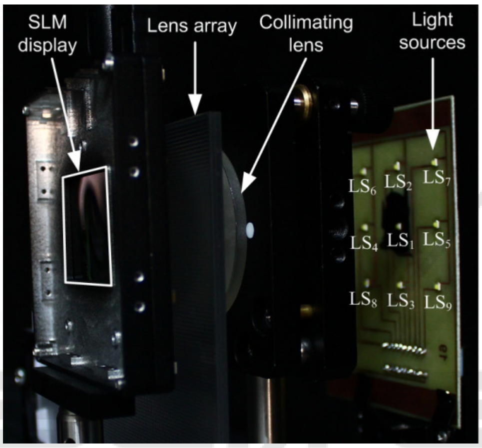

Figure 6: Set-up of the proposed method.

We used 9 (3×3) Light-Emitting Diode (LED) instead of the light sources to enhance the VA along horizontal and vertical direction, as shown in Fig. 6.

Figure 7(a) shows the experimental result of PLS when the just one source LS_1 is turned on. It is like the conventional PLS. When up source LS_2, center sources LS_1, and down source LS_3 are turned on and other LEDs are turned off, the results is shown in Fig. 7(b).

Therefore, PLSs in the middle are brighter and bigger than other PLSs. Figure 7(c) shows results when left source LS_4, center source LS_1, and right source LS_5 are turned on and other LEDs are turned off.

From the Figs. 7(b) and 7(c), the elemental lens, where in the center of PLS array, can collect rays from additional light sources, the lens array must be close to the collimating lens.

Therefore, we changed the distance between the lens array and the collimating lens from 50 mm to 5 mm. The PLSs are shown in Fig. 7(d). From Figs. 7(c) and 7(d), brighter part of PLSs are large when the lens array is close the collimating lens.

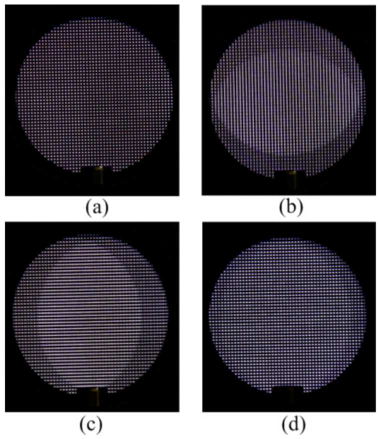

Figure 7: PLS displays in front view (a) the LS_1 LED turned on (b) the LS_2, LS_1, LS_3 LEDs are turned on (c) the LS_4, LS_1, LS_5 LEDs are turned on with l by 50 mm and (d) the LS_4, LS_1, LS_5 LEDs are turned on with l by 5 mm.

We took the pictures when the new method displays two objects where "A" and "T" are 10 mm and 20 mm from SLM, respectably. In the experiment, we displayed two InIms that are on the center view as shown in Fig. 8(c).

Figure 8: PLS displays of front view (a) left 18° (b) right 18° (c) center 0° (d) left 22° and (e) right 22°.

When we moved the camera from left to right, we took pictures in five different positions and measured the angle of the camera. After the invisible object "T", the angle of the camera from the right side is 18°. Before the invisible object "A", the angle of the camera from the left side is 18°.

Before the invisible objects "T" and "A", the angle of the camera from the left side is 22° and from the right side is 22°. Therefore, the VA of the objects “T” and “A” are 44°. From the experimental result, the VA is 2.55 times larger than the conventional method.

5 CONCLUSIONS

We use nine light sources to increase the diverging angle of the PLS along both of horizontal and vertical axis. The large diverging angle enhanced the viewing angle. When the distance between two light sources is given by Eq. equal to $s=f'\cdot P_L/f$, viewing angle of proposed method is 2.55 times larger than conventional PLS display. New method adds just light sources. It is different from other methods.

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