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ON A STUDY OF THE HOLOGRAPHIC 3D IMAGE RECONSTRUCTING SYSTEM ADOPTED WATER FLOW SCREEN

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ABSTRACT

In the holographic 3D display using the mist screen, large 3D images can be observed with wide viewing angle. However, in the previous methods, it was difficult to observe stabilized 3D images when an observer moves around the screen, because the mist flows. In this paper, we studied a process of 3D image projection employed the water flow. Our new imaging process presented here takes advantage of the water flow as a holographic 3D screen, and this process enables us to reconstruct stability than using the mist screen.

1. INTRODUCTION

In order to project a large holographic 3D image in the space, a spatial screen of the 3D images should be required [1-8]. For this, we have studied some projecting method with the use of mist screen to present holographic 3D images of moving pictures, and we have used water particles to reconstruct them[9,10]. However, to make use of it as a stable screen, there appeared to be several problems to be resolved, for instance, the structural form of the screen is variable if the flow of the mist is disturbed, the projected image happens to disappear on account of unstable mist flow, and so on. In this study, to improve such undesirable situations, we have developed a new water flow screen made of liquid form of the water particles, and made efforts to construct more stable screen for the projection of 3D holographic images.

Holographic presentation of moving pictures is very valuable idea as a process that enables us to reconstruct the images of 3D moving pictures in the space. On the other hand, it is known that the possible device of spatial light modulation has its criterion both in the pitch and the number of the pixels[3], and thus, it is considered to be difficult for us to present a large 3D image with a wide viewing range. From this consideration, it seems to be necessary to prepare the screen on which 3D images can be performed. As holographic processing, the writing process of reconstructed image in the crystals[7,8], the spatial projecting process using mist screen [6,9,10] and so on, are known to have been studied. By the reason that large sized images can be observed with wide viewing angle in the relatively easier way, we have studied the process which adopts the space obtained by jetting out the water particles in the mist form as a 3D screen, and we have made several improvements to realize a stable flow of the mist [9] and the one in the reforming of nozzles [10]. However, it seems to be more necessary to study and improve for the performance of a stable presentation of reconstructed images even if the mist flow is disturbed by the airflow.

In this paper, we will present a study of the process employed the screen of water flow (we shall call this as a water flow screen), where the water contains impurities. In addition, we will report that this process gives more stable performance of the recovered images than the one employed the mist screen.

2. 3D IMAGE PROJECTING SYSTEM

2.1 Outline of the system

Total scheme of 3D image projecting system used in the experiment is shown in Fig 1.

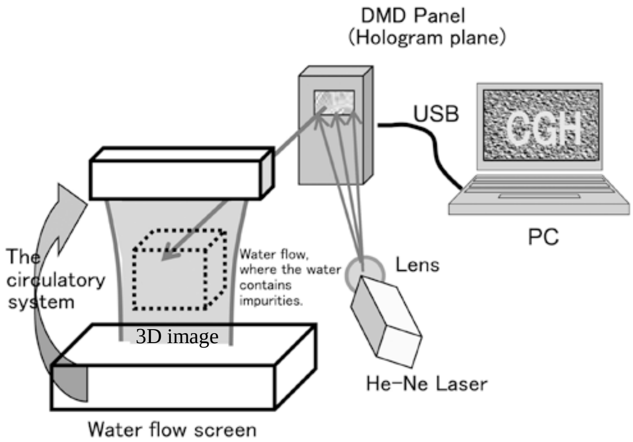


Fig.1 Outline of the 3D image projecting system

The system is composed of He-Ne laser, lens, DMD (Digital Micro-mirror Device) panel, water-flow screen which we have proposed here, and PC.
Here, we first expanded the width of the beam projected from He-Ne laser by lens, and tried to make it close to the spherical wave as much as possible. Then, we illuminated this wave onto the hologram plane (DMD panel) formed by the hologram produced by computer [9-11]. Next, projecting the reflected wave fronts from the DMD panel onto the water-flow screen, we performed the reconstructed 3D images in the space. Observation was made to the spatially reproduced images in such a way that the 0-th order transmitted light was not found in the viewing area. Several requirements needed for the construction of 3D spatial screen which we have proposed here will be discussed in the next section. In the experiment, we adopted the DMD Discovery Kit 4100 made by TI company as a DMD panel(see Table-1)[12], and it is shown in Fig 1.

Table-1 Specification of DMD Panel

Display size	0.9[in](XGA)
Refresh rates	360[Hz](panel only)
Contrast	420:1
Tilt Angle	12[deg]
Number of pixels	786,432 (V1024 x H768)
Pitch of pixels	13.6[μm] x 13.6[μm]
Size of pixel	12[μm] x 12[μm]

2.2 On the spatial water-flow screen

2.2.1 Making of spatial screen using water-flow

We have used the spatial mist screen formed by jetted water particles with the diameter from 2 [um] to 3 [um].[9,10,13,14] This comes from the reason that we can expect it as a 3D screen usable in the spatial projecting process that enables us to observe large reconstructed 3D images with a wide viewing area. But it has a drawback such that there appears a fluctuation or a partial image loss in the recovered images on account of the displacement of the observer near the screen simply because the water particles forming the screen are light and a breath of wind easily arises. This phenomenon seems to occur from the density-change of water particles. To improve this problem, we studied a water-flow screen made by circulating flow of the water which contains impurities (small particles). We think that this improvement seems to produce a more stable spatial screen of water particles.

2.2.2 A construction of water-flow screen

We shall explain how our water-flow screen has been constructed. Its outline is shown in Fig 2. The screen is made based on the following remarks: (1)-(5)

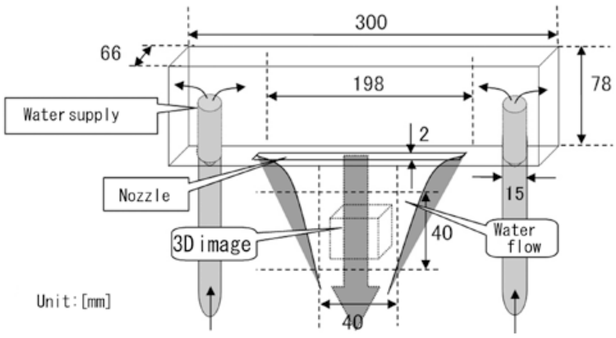


Fig.2 The construction of water flow screen

(1)Application of water-flow circulation:
It seems to be desirable that the screen is independent of the variations occurred from the other indirect experimental conditions, for example, water supply, and that it does not depend on the causal variations from inner devices of the system. For this reason, we have employed the pump which works for circulation of water. Water flows down to the tank from the outlet, and it is drawn up to the pool, and then, it flows to the outlet again, which forms a circulation of water flow. This process also plays a useful role to preserve the density of the scattered materials (particles), which we will explain afterwards, contained in the water.

(2)Water-flow screen formed by the water containing small particles as impurities:
When the water-flow screen is made of purely water particles, it was seen to be difficult for us to perform fully bright reconstructed images in the projecting process. (This will be discussed afterwards.) In the water-flow screen, water moves down just as a consecutive body of particles, while in the mist screen, water particles are scattered in the space with the size of 2[um]-3[um], and the images are formed by the scattering of reconstructing waves. For this reason, in the screen of purely water particles, low brightness seems to have been brought by insufficient scattering of reconstructing waves.
In this experiment, in order to get a full amount of scattering waves for reconstruction, we made a water-flow screen of water particles mixed with cream for coffee (the diameter: 0.1[um]-3[um][15]) as impurities, taking into account that both of two particles have nearly the same diameters. We expected that this consideration would give a nice effect to realize a stable movement of water particles forming the spatial water-flow screen.

(3) A technique for minimizing the effect of surface tension on the water-flow screen:
The left and right parts of the water-flow screen tend to move to the central part of it on account of the surface tension, as shown in Fig 2. To display large 3D images in the screen, we must adjust the amount of water outgoing from the faucet properly. Here, we

employed a slit of the size 198[mm] x 2[mm], so that the water could be suitably flown through this. In addition, we studied how to attain a stable presentation of the images without using multiple slits.

(4)A remark for obtaining uniform flow in the screen:
In water-flow screen, it is considered to be desirable that the water flows uniformly in the vertical downward direction. Since the size of the water outlet in the screen is 198[mm] x 2[mm], we must adjust the flow of the water so as to make it fit for the shape of the outlet, without directly connecting the outgoing faucet of the pump whose inner-diameter size is about 1.5[mm]. Like this way, we have adopted the scheme where the water drawn by the pump is not directly led to the outlet, but it flows down to the outlet uniformly in the working mechanism such that the water dashes against the surface of the pool and its flow is disturbed.

(5) Adjustment of the operation rate of the pump:
For the adjustment of total amount of water flowing in the screen, we investigated an optimal operation rate by changing the number of the pumps around 1-3. In this way, we made the water-flow screen adjustable by taking the balance between uniformity and disturbance in the flow.

3. RESULTS AND DISCUSSION

3.1 Improvement in stable presentation of the images on water-flow screen

As shown below, we see that the stability of the images displayed in the water-flow screen is much more improved than in the mist screen. To compare the level of stability, taking care that the images can be easily observed and the characteristics of longitudinal, vertical and oblique components of the images can be easily appreciated, we have taken up a figure of the star consisting of 364 points with 8[mm] x 8[mm].

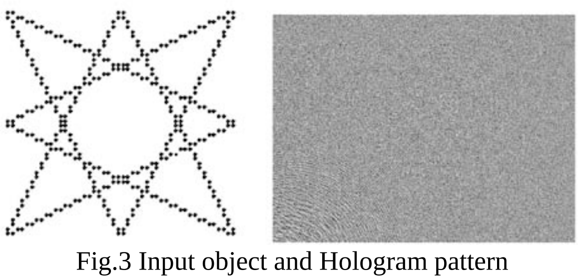
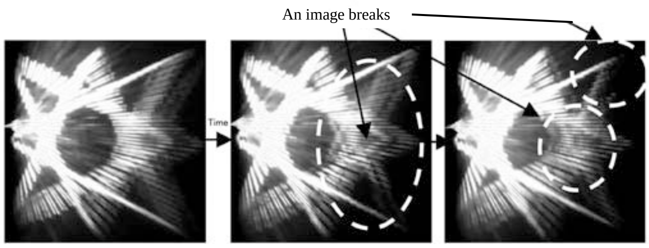
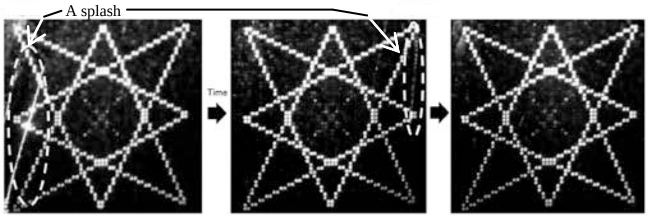


Fig.3 Input object and Hologram pattern

An example of the behavior of the projected image from the CGH in Fig.3 observed over a time span is shown in Fig 4.



(a) In the case of Mist screen (Reference [10])



(b) In the case of Water flow screen

Fig.4 Comparison of the reconstructed images

In Fig 4, (a) corresponds to the case of the mist screen, and (b), the water-flow screen. (Density 1.25[%], outflow 131[ml/s]) We can see from Fig 4 the following:

(1)In the mist screen, a small decay of the reconstructed image and a loss of the reconstructed figure are observed on account of the flickering of the screen.
(2)In the water-flow screen, any loss of the reconstructed images and fluctuation are almost not observed except for the effect of a water-spray.

This suggests that an improved stability is expected in the presentation of the images by using a water-flow screen.

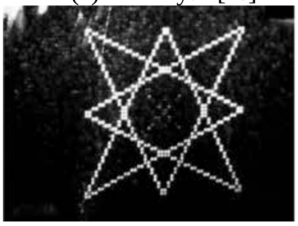
3.2 Consideration of the characteristics of the projected images on the water-flow screen when the water contains impurities with various mixing rate.

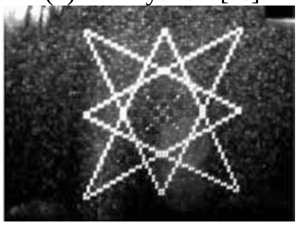
We investigated the characteristics of the reconstructed images projected on the water-flow screen by changing the mixing rate of the impurities. Here, we changed the mixing rate by adding the cream for coffee into the water circulating through the screen according to the rate of 0[%],0.13[%],0.26[%],0.645[%],1.27[%] and 1.88[%]. The mixing rate (density) is defined by the mass-percentage. Some results are shown in Fig 5.We found the following results.
(1) In case of 0[%]: Image is displayable by projection, but the brightness is very low.
(2)By increasing the mixing rate, the brightness becomes higher. It shows that the impurities seem to play the role of scattering of the material.
(3) Taking the mixing rate higher and higher, we see that the brightness of the background noise becomes also higher together with that of reconstructed image, and it appears to have the analogous characteristics of the images displayed in planar screen. It suggests

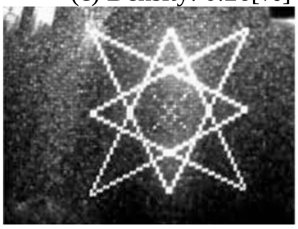
that the contrast of the images and the background noise are in the trade-off relation.


(a) Density: 0[%]


(b)Density: 0.13[%]


(c) Density: 0.26[%]


(d)Density: 0.645[%]


(e) Density: 1.27[%]

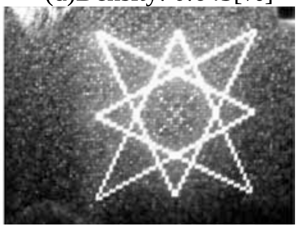

(f)Density: 1.88[%]

Fig.5 Reconstructed images changing the mixing Rate (density) of the impurities

In our experiment, relatively highly contrasted recovered images are observed when the mixing rate is set as 0.13[%] and 0.26[%].

3.3 A study of the characteristics of the reconstructed images on the water-flow screen observed when the outflow from the screen is changed:

The case when impurities are added. By increasing the number of the operating pumps, we changed the quantity of the water flowing out from the screen, and investigated how the characteristics of the reconstructed projected images changed. For this purpose, we controlled the outflow as 131[ml/s], 317[ml/s] and 410[ml/s]. Some results are found in Fig.6 and Fig.7.

From the results, we see that

(1)As before, the brightness in the images becomes high if the high mixing rate is used.

(2)The brightness in the reconstructed images are observed higher as the amount of water flowing out from the screen gets larger. This does not depend on the mixing rate. However, we see that the background noise also gets large. Since it has a trade-off relation between the contrast, to perform high-contrast images, proper adjustment of the amount and the mixing rate of the water flowing through the screen must be strongly required.

(3) Too much outflow of the water gives noise to the images as a spray, and so, we must take care of this. In our system, highly contrasted images were obtained under very small influence of background noise and spray when we observed on the following conditions:

(a) Mixing rate=0.13[%], Outflow=317[ml/s] and 410[ml/s].

(b) Mixing rate=0.26[%], Outflow=131[ml/s].

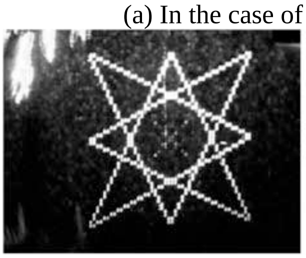

(a) In the case of outflow=131[ml/s]


(b) 317[ml/s]


(c)410[ml/s]

Fig.6 Reconstructed images changing the outflow (Mixing rate (density):0.13[%])


(a) In the case of outflow=131[ml/s]


(b) 317[ml/s]

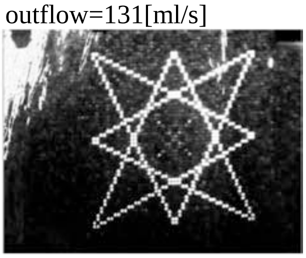

(c)410[ml/s]

Fig.7 Reconstructed images changing the outflow (Mixing rate (density):0.26[%])

3.4. A study of the characteristics of the reconstructed images on the water-flow screen observed when the outflow from the screen is changed:

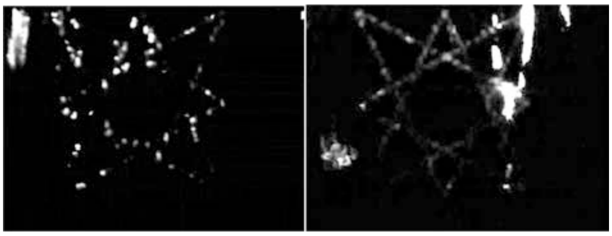
The case when impurities are not added. We shall give the results dividing into two cases:

・Observed with the 0-th order transmitted light not to be found in the viewing area

・Observed without taking into the above process

3.4.1 Results obtained when the 0-th order transmitted light was not found in the viewing area

In Fig.8, we show the reconstructed projected images when the outflow is set 317[ml/s] and 410[ml/s], respectively. From these, the brightness in the image becomes high as before if the outflow is made larger, however, this brightness seems to be insufficient as a screen.



(a) Outflow: 317[ml/s] (b) 410[ml/s]

Fig.8 Reconstructed images when the 0-th order transmitted light was not found in the viewing area

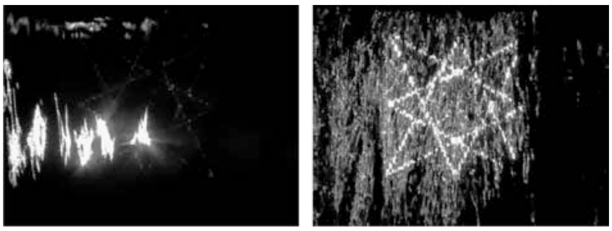
3.4.2 Results obtained when the above process is not taken in.

Here, we compare the results obtained when the screen is heavily disturbed and the ones obtained when the effect of disturbance is very little. These two environments were constructed by changing the positions of the pumps. (see Fig.9)

Fig.9 shows that

(a): reconstructed images can be confirmed, but the background noise, which looks like a spray, is coming into the viewing area. This phenomenon was brought by the 0-th order transmitted light. If the transmitted light strongly appears, the direct view of the image may be very difficult to obtain.

(b): If the disturbance is large, the reconstructing wave is diffracted, and thus, the effect of the noise caused by the transmitted light may be smaller. As this result, almost all part of the reconstructed image seems to come into the viewing area. However, fluctuations begin to appear in the reconstructed images as the time passes by.



(a) Outflow: 317[ml/s] (b) 410[ml/s]

Fig.9 Reconstructed images when the above process is not taken in.

4. CONCLUSION

In this paper, we introduced a new water-flow screen, and investigated the characteristics of reconstructed projected images in several points. As this result, we found that by mixing other impurities with the water, we could construct a more highly stable 3D water-flow screen. In this study, we made the experiment preparing the screen whose depth was 2[mm]. We think that in order to make one feel higher 3 dimensional sense as a 3D screen, it seems to be effective to produce a screen with deeper width. In addition, some consideration may be necessary to the shape of the outlet, and to the multiple structure of water-flow screen. We would like to study and report about these points near in the future. This research was partially supposed by the Gran-in-Aid for Scientific Research (No.21300318) in Japan.

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