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# Achieving the Naked-eye 3D Effect for Right-angled LED Screen by Off-line Rendering Production Method

Fu Linwei[1], Zhou Jiani[2], Tae Soo Yun[3*]

*[1]Ph. D student, Department of Visual Contents, Dongseo University, Korea*
*[2]Assistant professor, Department of Film&VFX Internatinal College, Dongseo University, Korea*
*[3*] Professor, Department of Digital Contents, Dongseo University, Korea*

*E-mail:flw0819@gmail.com, moses472530@gmail.com, yntaesoo@gmail.com*

***Abstract***

*As a new trend in the development of urban public spaces, the use of right-angle LED screens perfectly combines building facades with naked-eye 3D visual effects, providing designers with a brand-new creative platform. How to create a realistic naked-eye 3D effect on a right-angle LED screen and bring an immersive visual experience to the audience has become a question worth exploring. So far, production companies have yet to announce the relevant design ideas and complete production methods. In order to explore the production principle and production process of the naked-eye 3D effect of the right-angle LED screen, we summarize the basic production principle of the naked-eye 3D impact of the right-angle LED screen through case analysis. Based on understanding the production principle, the actual case production test was carried out, and a complete production process of the naked eye 3D visual effect of the right-angle led screen was tried to be provided by off-line rendering. For the problem of how to deal with image deformation, we provide two production methods: post-production software correction and UV mapping. Among them, the UV mapping method is more efficient and convenient. Referring to this paper can help designers quickly understand the production principle of the naked eye 3D effect of right-angle LED screens. The production process proposed in this paper can provide a reference for production method for related project producers.*

***Keywords:*** *3D production; Naked-eye 3D; Right-angle LED screen; Perspective;*

## 1. Introduction

At present, naked-eye 3D technology is still a long way from large-scale commercial applications. Still, the considerable demand from advertising, public display, exhibition, and other fields will further promote technology development. The naked-eye 3D effect of the right-angle LED screen quickly meets the needs of this industry under the current technical constraints. Because its essence is not true naked-eye 3D but a "pseudo" naked-eye 3D effect corresponding to human optical illusions, this kind of display method eliminates the limitation of naked-eye 3D technology in the true sense. It presents a complete naked-eye 3D visual

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Corresponding Author: yntaesoo@gmail.com
Tel:*** - **** - **** Fax: +82-10-4143-6548
Professor, Department of Digital Contents, Dongseo University, Korea

experience to the audience [1]. It will show tremendous application value and commercial value in the future. Based on this research background, this paper explores the naked-eye 3D production principle and production process of right-angle LED screens.

In terms of research methods, based on case analysis, this research divides the production of naked eye 3D of right-angle LED screen into three parts: source production, screen deformation, and delivery test, and proposes a complete production process. Virtual source production is mainly carried out in 3D digital software. Through several methods commonly used in 3D modeling, such as perspective structure, lines, light and shadow, and color contrast, a three-dimensional virtual space is constructed as the primary visual object of the naked-eye 3D effect [2]. According to the analysis of the naked-eye 3D production principle of right-angle LED, the realistic perspective relationship is the precondition to ensure that the audience can see the natural 3D effect. Therefore, how to ensure that the video source produced in 3D software can accurately restore the perspective relationship with the audience on the LED screen has become a vital issue in exploring this type of production process. In response to this problem, this paper uses two different ways of outputting through post-correction in After effect and UV mapping in 3D software. Under the premise of the same product, the UV mapping method simplifies the post-correction process and has higher production efficiency [2, 3].

## 2. Related Research

### 2.1 Case study of naked eye 3D on right-angle LED screen

In the center of Times Square in Gangnam District, Seoul, there is a billboard with the most giant LED screen in Korea, 20 meters high and 80 meters wide. Korean visual team d'strict designed him into a public multimedia installation, "Wave", through this LED screen. The fantastic effect of simulating the turbulent tumbling of the waves inside the building has attracted global attention. Through the impact of naked-eye 3D visual technology, this screen is turned into a concrete transparent water tank. This case cleverly combines the two sides of the right-angle LED screen with the two sides of the background cube box, forming a semi-open three-dimensional space effect similar to a glass water tank for the audience. At the same time, the existence of auxiliary structure lines in the background enables the audience to form a completely closed expansion space cognitively [3].

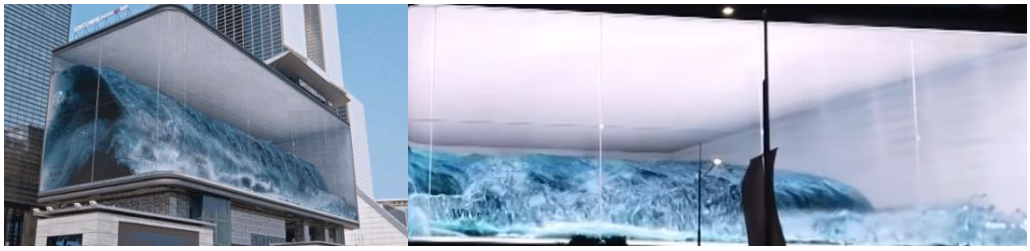


**Figure 1. "Wave", a public multimedia installation in Seoul d'strict**

The current naked-eye 3D technology cannot be considered naked-eye 3D in the true sense. Because these large screens can only have a relatively stereoscopic solid effect when viewing a specific video screen customized for the giant screen at a particular angle. Otherwise, the picture will be distorted. As shown in Figure 1, the above is a specific viewing angle, and the audience can obtain a complete naked-eye 3D visual effect. The following is the viewing angle of the correct view. The waves and background structure lines in the picture are all stretched.

Another way to create a visual 3D stereoscopic effect is to develop a sense of depth on a plane by creating an inner space to achieve a three-dimensional feeling [4]. Whether on a large flat screen or video content on a giant curved screen, it is common to develop a sense of a three-dimensional space inside the screen.

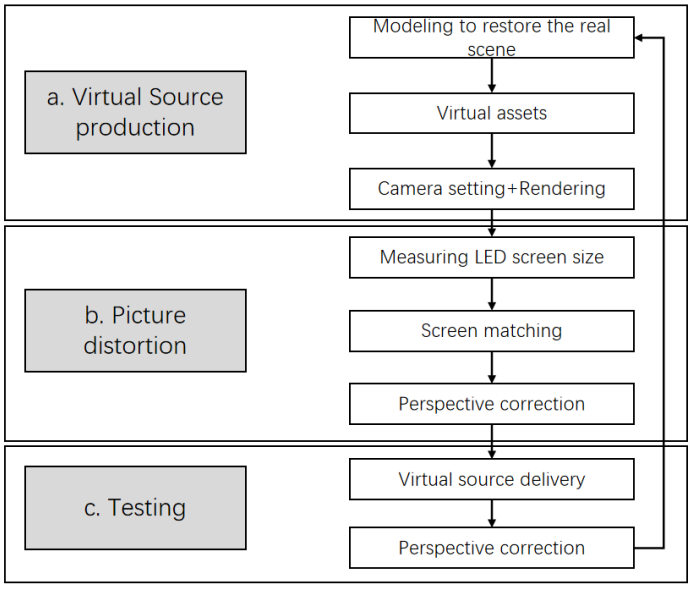



**Figure 2. Right-angle LED screen naked eye 3D effect production process**

According to the case study, two conditions must be met to achieve the naked-eye 3D effect on the right-angle LED screen. The first is to make sources corresponding to the perspective relationship according to the audience's position. Ensuring that the perspective relationship and the spatial structure are accurate in this perspective is the prerequisite for ensuring the naked-eye 3D effect. The second is to create a structural space in the background of the picture to enhance the sense of three-dimensional space. According to these two necessary conditions, it can be divided into two parts: video source production and picture deformation. In the production of a video source, a three-dimensional virtual space is constructed by 3D software. Then the screen deformation is used to ensure the accuracy of the perspective structure. After completing the production of the source part, re-calibrate the picture according to the actual effect of the on-site delivery, and finally, achieve the purpose of accurately outputting the naked-eye 3D result. The general process can be summarized into three parts: virtual source production, screen deformation, and on-site delivery test, as shown in Figure 2.

### 2.2 Production principle of naked eye 3D effect of right-angle LED screen

The naked-eye 3D effect of a right-angle LED screen is based on the basic principle of applying optical illusion art. The human eye can see a large LED display screen with a three-dimensional display effect without the help of visual aids such as polarized glasses. It is a brand-new way of media presentation [5]. They use the structural characteristics of right-angle LED screens and professional 3D video sources to present visual shock and impact with perfect display effects, breaking through the boundaries of optical illusion art and subverting traditional Flat video display mode. This step applies the principle of optical illusion art, combining the three-dimensional plane figure with the three-dimensional space and presenting the three-dimensional space effect on the plane [6]. The rule of ordinary painting is to be near big and far small, nearly real and far virtual. The picture perspective does not refer to the viewer's point of view, and the composition of the picture is based on

the perspective of the picture itself. The law of the three-dimensional painting of optical illusion art is that the near is small and the large is large, and the far and near are both real. The perspective of the picture refers to the viewing position of the viewer. The composition of the whole picture takes the human viewpoint as the visual origin so that the three-dimensional painting is not only a picture but also creates a real visual space, and the viewer can integrate into the picture [7]. As shown in Figure 3, when the cube in the actual distance is presented on the plane in an optical illusion, the perspective relationship corresponding to each point is based on a fixed visual origin. At this time, the cube coordinate axis XYZ displayed on the plane is the perspective relationship with each vertex that has changed correspondingly. The principle is similar to the point light projection phenomenon.

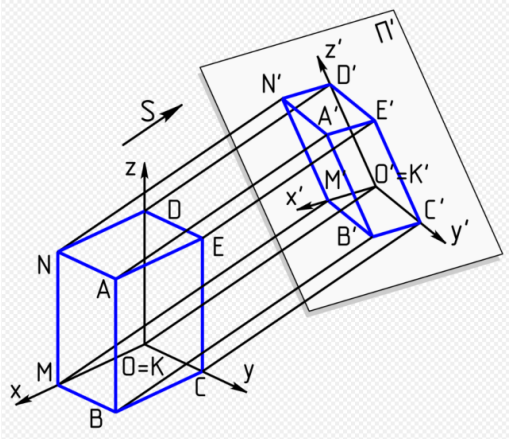



**Figure 3. Correction principle of perspective relationship of right-angle LED screen**

The technical principle is to set the primary viewing angle range, calibrate the viewing angle and distance of the audience, and reconstruct the 3D model according to perspective elements, visual subjects, and environmental elements. Combined with the installation position of the LED display screen and the distribution of the audience, the perspective relationship of the visual subject content is obtained.

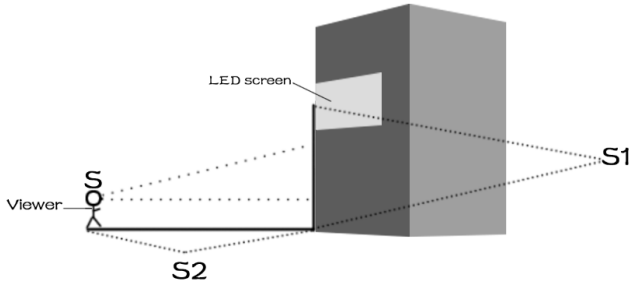



**Figure 4. Side view of right-angle LED screen perspective relationship description**

As shown in Figure 4, where S is the best visual range of the human eye, S1 is the height of the right-angle LED screen, and S2 is the viewing distance of the audience. According to the above three elements, specific parameter settings can be obtained and combined with the actual application scenarios. Through 3D modeling, those three elements can be correspondingly restored in digital software, and the same perspective relationship can be reconstructed in the virtual scene. A fixed virtual camera is set at position S to simulate the picture viewed by the human eye. After that, the visual subject elements and the perspective relationship design take S as the primary perspective relationship reference. In this way, the pictures in the three-dimensional virtual scene can be accurately conveyed to the actual audience with the same perspective relationship. S is the vertical

viewing angle range of the human eye, and the steep angle is 135 degrees, so as long as it is within this range, the perspective relationship design of the video content is reasonable. Taking advantage of this can provide designers with more creative space [8].

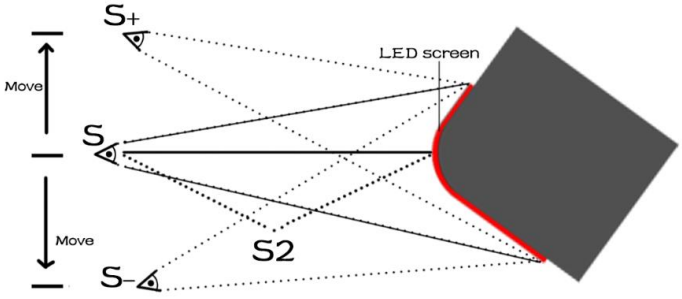



**Figure 5. Top view of right-angle LED screen perspective element description**

After determining the specific value of the vertical relationship, another thing to pay attention to is the position of the viewing angle on the horizontal relationship. Combined with the principle of optical illusion art, the most significant limiting factor of its naked-eye 3D effect is the optimal viewing angle. Like optical illusion art, the naked-eye 3D product in the right-angle LED screen also has the problem of the best viewing angle, and the audience can only see the real three-dimensional impact at a certain angle [9]. As shown in Figure 5, when S moves to S+ or S-, under the premise of maintaining the same viewing distance S2, the right-angle LED screen is regarded as a three-dimensional structure, and the perspective relationship in the visual range seen by the audience changes. This issue is explained in detail later. Therefore, the perspective relationship brought by the best viewing angle must be considered when determining the virtual camera position. Once the horizontal position of the camera is selected, the source production of the entire visual subject must follow this perspective relationship without deviation. It should also be consistent when reversing the perspective relationship of point, line, and plane in the future. This is critical to ensure the naked eye 3D effect in the right-angle LED screen [10].

## 3. Off-line rendering method of right-angle LED screen naked eye 3D effect production method

### 3.1 Off-line rendering method production process

3D source production is the same as traditional CG production, creating 3D scenes and main objects and then adding animation to the main objects. The reverse perspective relationship includes two parts: rendering the camera perspective relationship and post-production perspective correction. A unified way of the three positions is determined to ensure that the perspective relationship of the video source is consistent with the visual experience of the actual viewer. That is, the position of the audience, the simulated audience's virtual camera position, and the final rendering camera position are consistent. This method can ensure that there is no deviation between the perspective elements in the virtual scene and the actual scene and that the naked-eye 3D effect is accurate. The process is mainly divided into three parts: virtual source production, screen deformation, and delivery testing.

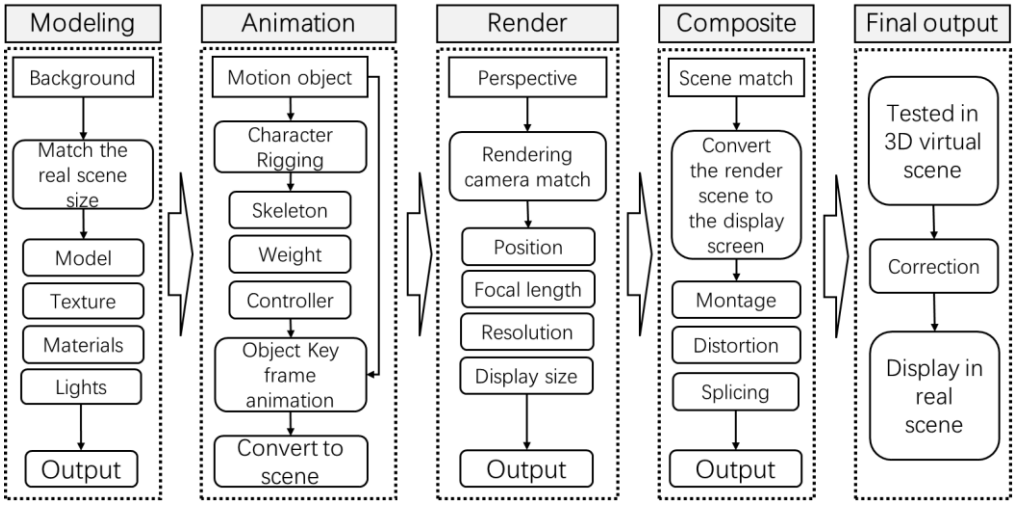



**Figure 6. Flowchart of off-line rendering**

### 3.1.1 Virtual source production

Create the project at this stage. The primary consideration is creating virtual sources that conform to the relationship between the naked eye's 3D perspective and space. As shown in figure 6. Modeling can be used to restore the naked-eye 3D effect accurately. It is worth noting that the screen size and the position of the rendering camera must be consistent with the actual scene. This is the primary premise of any naked-eye 3D project production. The prospective relationship of the entire scene and animation motion tracks must be set according to these scale and position relationships. After the modeling is completed, animation is usually added to the 3D scene, and the dynamic video material is rendered and output.

### 3.1.2 Screen deformation

After the complete video source is rendered and output, the video needs to be re-edited in the post-processing software. In this paper, we adopt the method of cropping the picture into two parts according to the center line of the rendered sight. The left side is the right-angle LED screen. The right image is the right side of the right-angle LED screen, and the factory uses the Corner Pin plug-in in the After effect. By using this plug-in to handle the distortion of the screen, the perspective relationship of the rendered output image can be changed as a whole. It does not affect part of the picture. This principle is similar to the distortion function of Photoshop, but AE can process video sources, while PS is limited to photo references. Through the adjustment on AE, the premise that all perspective relationships are changed as a whole, the divided left and right parts of the source match the size of the LED screen. Through manual deformation, the deformation problem of the screen can be solved very directly.

### 3.1.3 Actual test

Since this research did not test the actual LED screen as the output end, the natural test phase chose to simulate in virtual software. This post-production software synthesis method to deal with screen deformation can affect realistic naked-eye 3D effects and synchronize video sources. Play in the virtual scene, mimic the audience's visual effects, and get an excellent visual experience.

## 3.2 Practical case test

Based on the analysis of the case, a simple case production is carried out using 3D modeling software. The

primary purpose of this case is to explore the production principle and production process of the naked-eye 3D effect of the right-angle LED screen, so the picture quality and production accuracy are low. As figure 7 shows. According to the structural characteristics of the right-angle LED screen, a corresponding three-dimensional scene was created. Six blue spheres of different sizes replaced the main visual object and made a simple displacement animation.

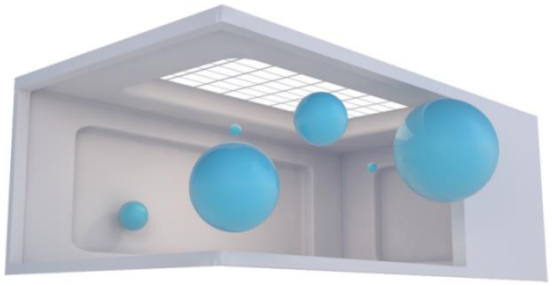


**Figure 7. Right-angle LED screen naked eye 3D effect case production renderings**

The perspective relationship and 3D effect shown in the figure are the effects seen by the final audience. This picture cannot be played on the screen as the last output picture. According to the naked-eye 3D effect principle of the right-angle LED screen in the previous article, it can be known that on this basis, the perspective relationship needs to be reversed through the screen deformation in the second step. Use post-production software to correct the perspective relationship to reverse the naked-eye 3D effect on the plane.

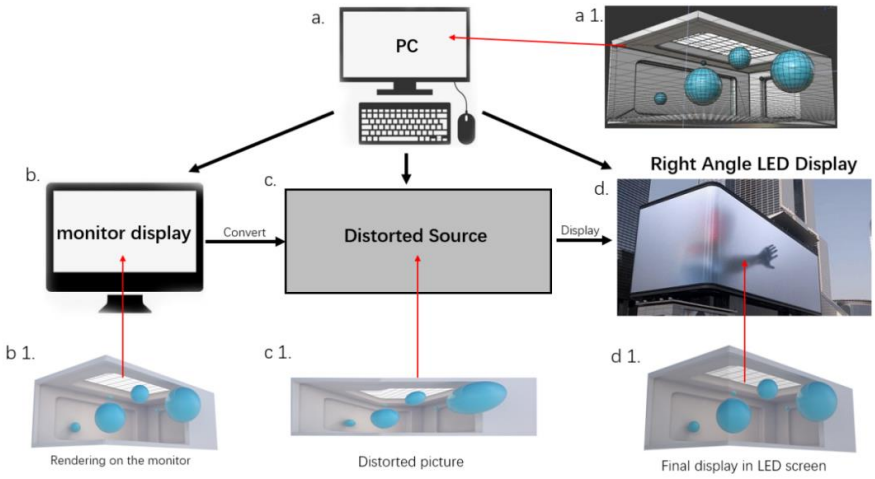



**Figure 8. Instructions for Maya + AE production**

Currently, most naked-eye 3D projects mainly produce corresponding sources through offline rendering, then distort the sources according to the display characteristics of right-angle LED screens. As shown in Figure 8, “d” is a real advertising case from the center of Times Square, Seoul. To achieve this effect, the process from “a” to “b” is the production process of the virtual source. The main workflow is to create the corresponding virtual source based on the initial script design. These include virtual scene modeling, animation, lighting, materials, and final render output. “a1” and “b1” are the corresponding production contents, respectively. The process from “b” to “c” is the screen deformation process. The naked-eye 3D effect of the right-angle LED screen mainly uses the parallax and optical illusion of the human eye. So, the final picture is still flat, and the source completed in the virtual production stage cannot be directly applied to the output end.

Therefore, it is necessary to reprocess the deformation of the picture to maintain the perspective relationship and the three-dimensional space structure. The virtual source is directly displayed on the LED screen and converted into a video source that can be played. The conversion process is shown in Figures “b1” to “c1”. The third step is accurately displaying the processed image source on the right-angle LED screen. In this process, it is necessary to return to the source production stage according to the actual scene situation and re-adjust the details of each picture to ensure a complete naked-eye 3D effect. As shown in “d1”, the image of “b1” is accurately conveyed to the LED screen and finally brought to the audience.

There are many ways to make 3D virtual sources, so that I won't go into details here. The focus of this study is to explore how to deal with screen deformation. Currently, the naked-eye 3D project of a right-angle LED screen is in the development stage. Since no manufacturer has announced the production process of screen deformation, this issue deserves further exploration.

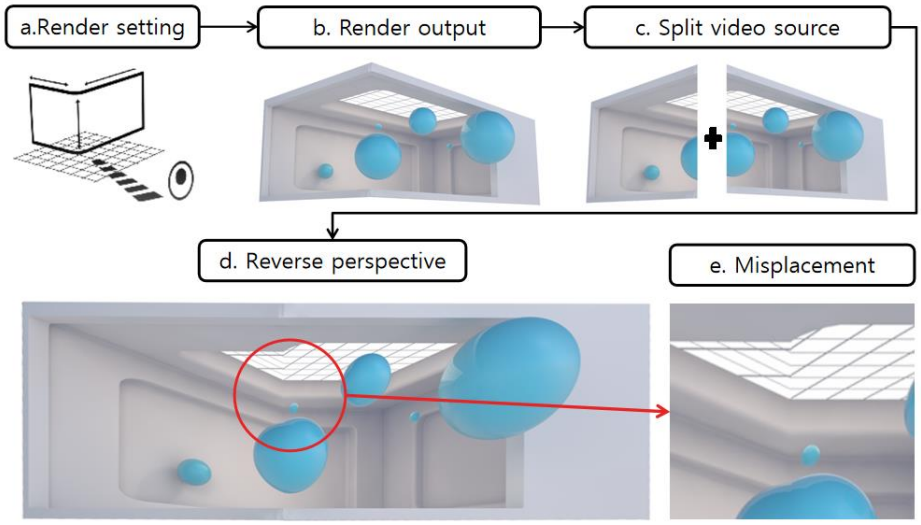



**Figure 9. Flow chart of perspective relationship correction**

In this paper, Adobe After Effect software is selected to correct the video source. According to the performance principle of the naked-eye 3D effect of the right-angle LED screen, the rendered image is divided into two parts, left and right, corresponding to the left and right screens of the right-angle LED screen. Then use the corner positioning tool to reverse the perspective relationship and deform the picture to make the final output picture match the screen. As shown in Figure 9, from step "a" to step "d", the specific screen conversion process is described. But the final output picture will have a misplacement problem at the junction, which can be repaired manually using the Liquify tool to make the junction of the images more natural.

### 3.3 Make picture distortion by UV mapping

In order to ensure that the perspective relationship of the rendered output source is consistent with the perspective relationship viewed by the human eye, it is necessary to set the position of the rendering camera to be compatible with the part of the observer. Although this can ensure the naked-eye 3D effect of the rendered picture, it cannot be directly played on the screen as a video source. Therefore, it is necessary to re-calibrate the matching of the rendering source and the screen in the later stage and reverse the perspective relationship (Reverse perspective). In this paper, the Adobe After Effect method is used to split the rendered source and

then stretch and tile it onto the UV of the screen to solve the problem of reverse perspective. This production method requires switching between two production software, and the production process is relatively complicated. In order to simplify the production process, this paper uses the UV mapping principle in 3D software to deal with the perspective relationship and directly output the deformed source.

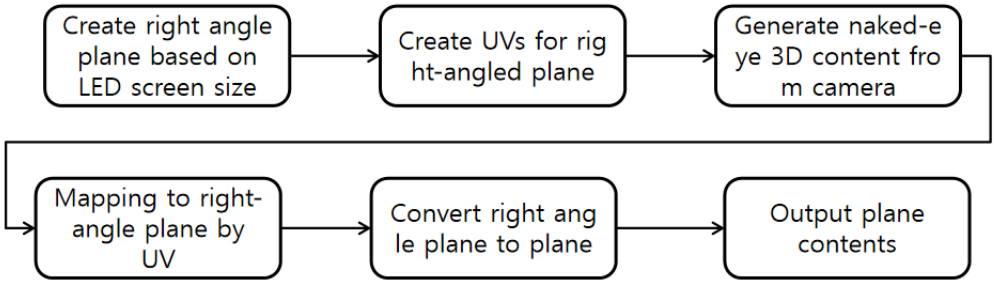



**Figure 10. UV mapping method to reverse the perspective relationship process**

The production method directly replaces the LED picture with a plane in the 3D software. It adopts the approach of unfolding UV and UV mapping to complete the deformation processing of the photograph. Compared with the previous method, this production method saves the adjustment process in the post-production software AE. It can directly render the whole picture after the 3D software output matches the vision, saving production time. The detailed production process is shown in Figure 10.

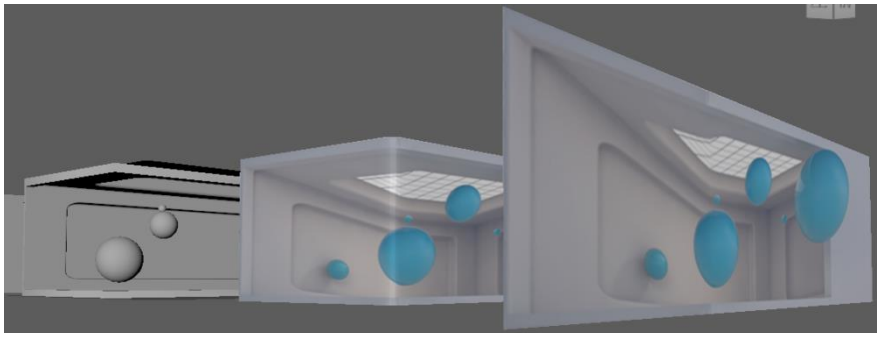


**Figure 11. UV mapping method to create screen deformation**

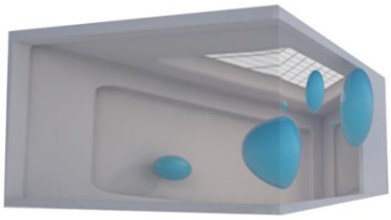
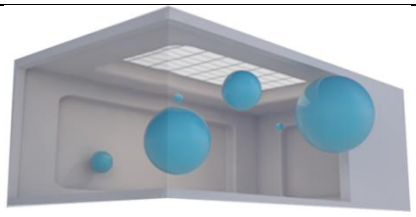
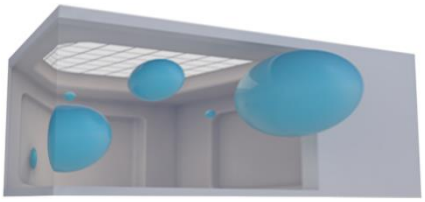
Compared with the need for picture editing and left and right picture recalibration in the later software, this production method utilizes the automatic calculation capability of the 3D software to generate seamless deformed pictures directly. In Blender, relying on this production principle, the deformed animation can be directly output, presently used for the LED screen as a source. Figure 11 is the deformed image directly output by UV mapping method

### 3.4 Analysis and future research

After completing the perspective relationship correction of the rendered output source, import the seed into the right-angle LED screen restored by proportional modeling in the way of Video texture, and stimulate the audience's perspective S inspection, which can accurately present the naked-eye 3D effect. The screen is stretched to different degrees when viewed in two positions, S+ and S-. In this way, the naked-eye 3D impact of the right-angle LED screen is consistent with the performance principle of optical illusion art. The naked-

eye 3D effect can only be obtained at a particular viewing angle (viewing angle S), and the position change will destroy the visual experience of the naked-eye 3D effect, as shown in the table 1.

**Table 1. Right-angle LED screen viewing angle description**

| Audience location | Preview screen | Introduction |
|---|---|---|
| **S+** |  | The left side of the screen is obviously stretched, the proportion of the left screen increases with the position, the perspective relationship is chaotic, the image at the connection between the left and suitable screens is abnormal, and the 3D stereoscopic effect is lost. |
| **S** |  | The picture is not stretched, the left and right picture ratios are kept the same as the pre-rendered picture, the perspective relationship is the same, and the naked eye 3D effect is the same. |
| **S-** |  | The right side of the picture is stretched. The proportion of the right picture increases with the position movement, the perspective relationship is chaotic, the image at the connection between the left and right pictures is abnormal, and the 3D stereoscopic sense is lost. |

The expression principle of the naked-eye 3D effect of the right-angle LED screen is the same as that of the optical illusion art, both of which have the problem of a single perspective. Optical illusion art is based on the plane effect. When the viewing position of the audience changes, it is always the state of facing the picture, and the problem could be more straightforward. As a new form of expression, a right-angle LED screen breaks through the limitation of optical illusion art on a single plane. The audience faces no longer a single plane, but a three-dimensional picture and the viewing angle is increased from the original 180 degrees to 270 degrees, as shown in Figure 10. When the audience position changes from S to S+, the picture on the screen still shows the perspective relationship of the best viewing angle so that the image will be stretched and the original naked-eye 3D effect will disappear. In the follow-up research, we will use the real-time rendering function of UE4 to realize the real-time interaction between the audience and the screen through position tracking. The naked-eye 3D effect with the correct perspective relationship can be seen at any viewing angle.

## 4. Conclusion

In order to understand and explore the production principle and complete production process of the naked-eye 3D effect of the right-angle LED screen, based on case analysis, we divide the production of the naked-eye 3D of the right-angle LED screen into three parts: source production, the screen distortion, and delivery test. The complete production process for the naked eye 3D effect of the right-angle LED screen is proposed

through the actual case production. According to the production principle of the right-angle LED screen, it is proposed that screen deformation is the crucial step to ensure the naked eye 3D effect. On the premise of ensuring that the viewing angle of the audience is consistent with that of the camera in the virtual environment, the perspective relationship can be accurately conveyed in the output image by inversely calculating the perspective relationship in the picture. In response to this problem, we adopt two different ways of outputting through post-correction in After effect and UV mapping in 3D software. Under the premise of the same product, the UV mapping method simplifies the post-correction process and has higher production efficiency.

Through the analysis of the case production results, it is found that the expression principle of the naked-eye 3D effect of the right-angle LED screen is the same as that of the optical illusion art, and there is a problem with a single perspective. The follow-up research will solve this problem as the starting point and use the real-time rendering function of UE5 to realize the real-time interaction between the audience and the screen.

## Acknowledgement

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