A larger and farther smartphone screen with 3D visual effect

His-Hsun Chen[1], Shuan-Yu Huang[2], and Chi-Ting Horng[3,*]

[1]E-Lead Electronic Co., Ltd, Changhua, 509, Taiwan
[2]School of Optometry, Chung Shan Medical University, Taichung 402, Taiwan
[3]Department of Ophthalmology, Zuoying Branch of Kaohsiung Armed Forced General Hospital, Kaohsiung, Taiwan
Email: h56041@gmail.tw

Abstract: The Project Air is a device that projects smartphone screens midair by utilizing the same technology as the Heads-Up Display (HUD) in the automotive industry. The Project Air consists of a smartphone holder, a concave mirror, and a convex mirror. In this configuration, the smartphone screen will be magnified up to five times and be virtually displayed as far as one meter behind the concave mirror. Besides, a type of mechanism to help smartphone to give immersive 3D effects to normal 2D videos or images is also developed. Through visual experience and visual feeling of human visual system, users will be able to enjoy comfortable 3D effects. As a result, the Project Air can keep the user safe from threats of vision impairment and obtain 3D visual effects.

[His-Hsun Chen, Shuan-Yu Huang, and Chi-Ting Horng. **A larger and farther smartphone screen with 3D visual effect.** *J Am Sci* 2017;13(12):33-36]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 5. doi:10.7537/marsjas131217.05.

Keywords: Project Air, smartphone screens, Heads-Up Display, human visual system.

Introduction

The current trend for 3C products is being as compact and lightweight as possible. However, the minimum sizes of these products have been constrained by the limits of human eyesight. This biological barrier is very difficult to break through, so the smallest smartphones vary between 4.5 inches to 6.5 inches. But with the development of wireless broadband technology, one of the main functions of a smartphone has become video streaming. As a result, staring at a small screen for long periods of time has become one of the greatest threats to our eyesight. Research has proven that, apart from genetic factors, staring at things too closely for a long time is the main causes of near-sightedness. [1] According to Omid Kordestani, Google's Chief business officer, "On mobile, the average [YouTube] session is now over 40 minutes". The potential damage to our eyes is not limited to near-sightedness. Strong blue light sources on smartphones increases the risks of presbyopia, cataract, and macular degeneration. [2] Since we are more reliant on our smartphones than ever, it is important for users to use smartphones in a healthy way. A practical solution to this issue would be projecting an enlarged screen far from the user.

Two facilities can be employed to enlarge the image, tablets and smartphone screen magnifiers. Tablets are basically scaled up smartphones. However, the increased size of tablet makes it less portable and the screen is only about twice the size (from a 6-inch smartphone to a 10-inch tablet). Tablets are also often held by two hands, making it almost as harmful to our eyesight as traditional smartphones. The current smartphone screen magnifiers on the market use Fresnel lenses. But these products could only enlarge the screen within a certain level. The smaller and lighter Fresnel lens has a similar function with concave lenses. The Fresnel lens is a film with numerous concentric circles on the surface to catch and reflect light, allowing it to magnify an image without being too thick or heavy. [3-5] However, the image quality is poor and creates glare on the edge of these concentric circles where light is deflected. Furthermore, the edges of the concentric circles are fragile and easily scratched. The Fresnel lens smartphone screen magnifier, as a product, cannot satisfy the customer's needs.

Here, we introduce a design that uses heads-up display concave lens optical technology to magnify and project a smartphone screen. We call it "Project Air". The Project Air can not only enlarge the image from the smartphone screen, but also provide 3D visual effect from the 2D image.

Principle

The Fig. 1 below demonstrates the optical physics of concave lenses. [6] In the formula, the concave lens projector would project an enlarged object "M" times larger at the distance "di". In a vehicle heads-up display device, the object refers to the projector (usually a 1.8-inch ultra-light TFT). For the Project Air, the object is the smartphone screen, the distance between the smartphone screen and the concave lens "do" is directly proportionate to the magnification scale "M" according to the formula [7]

$$\frac{1}{d_i}+\frac{1}{d_0}=\frac{1}{f}, M=\frac{h_i}{h_0}=\left|\frac{d_i}{d_0}\right|$$

where "f" is the focal distance between the concave mirror and the projected distance. For example, if the distance between a projection object (such as a smartphone screen) and the concave lens with focal distance 25cm (f = 25) is 20cm (do = 20), the magnification scale "M" will be 5; a 6-inch screen could be projected into a 30-inch screen 1 meter (di = 100) behind the concave lens (di = -100). Due to optical physical limitations, the 30-inch screen and 1 meter projection distance will not change according to the position of the user's eyes. This guarantees a minimum distance of 1 meter between the viewer and the screen. This is the ideal solution to reduce the risk of near-sightedness caused by staring at objects without adequate distance for long periods of time. The large clear screen can also greatly increase the smartphone-using experience of those burdened with presbyopia. However, the projected image is reversed compared to the original image (see Fig. 2). For heads-up displays, the problem can be solved by producing a reversed image. In Project Air, we added another mirror so the image will be reflected twice to solve this issue.

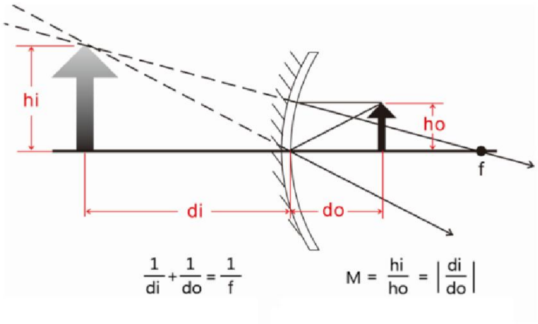

Fig. 1. The optical physics of concave lenses.

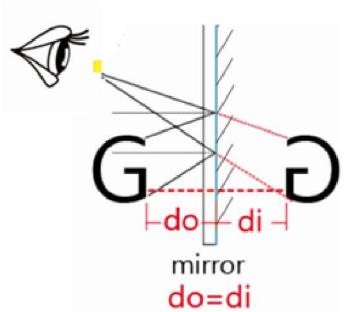

Fig. 2. The projected image is reversed compared to the original image.

The design of Project Air also provides 3D visual effect from 2D images. We use Fig.3 to illustrate the principle. The picture shown in Fig. 3 includes a path with houses on one side leading to the horizon. We print out the picture and place it parallel to surface A and call it image N. Although the picture is in 2D, it is obvious to most viewers that the road is parallel to surface C, almost perpendicular to the Z-axis of surface A, one side of the house is almost parallel to surface A, and the fronts of the houses are parallel to surface B, standing up in the Y-axis. Although image M is in 2D, we can recognize 3D aspects of the picture. Unfortunately, it is not realistic enough, so we would still perceive it as a 2D image.

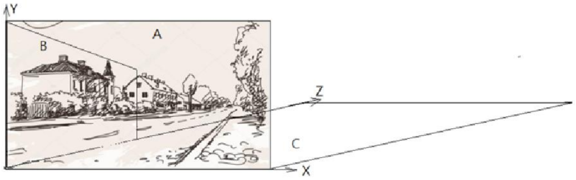

Fig. 3. The design of Project Air provides 3D visual effect from 2D images.

Let us tilt image N so it is perpendicular to surface B and between surfaces A and C like in Fig. 4 and call it image M. We then used image adjustment techniques to change magnification ratios and the tilt angle until images M and N completely overlap at view point P. We then remove image N and observe image M. At first glance it seems to be similar image N, there is a more immersive and realistic feeling to this picture because the road extends along the Z-axis really and the houses seem to stand on the Y-axis.

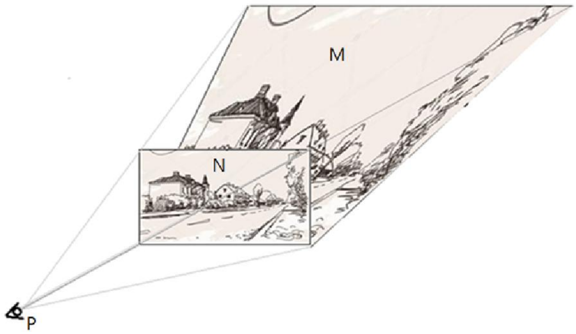

Fig. 4. Tilt image N so it is perpendicular to surface B and between surfaces A and C like, and call it image M.

We are about to introduce a method for normal 2D content to exhibit 3D effects using optical physics. First, let's discuss how someone can experience a feeling of impressiveness from a 2D image. A human's eyes act similarly to the camera described in Fig. 3. Humans can, through visual experience, perceive an object is extending into the distance if it decreases in size as it moves higher on a 2D plane. But if the object doesn't change in size, humans perceive the image as tall rather than far. Visual experience is accumulated by perceiving distance and size of everyday objects; eventually, being able to determine an object's size and distance just by looking at it. Therefore, in a painting, an object's size and location is important in creating an immersive effect. This ability can be used by just one or both eyes. When looking with both eyes, humans can perceive depth by piecing together the slightly different views of each eye. Although both eyes are looking at the same object, both eyes see things a bit differently, especially in the x-axis. The closer the object is, the greater the disparity. This is known as visual feeling and it is the main theory behind 3D movies and 3D television. By filming with a dual lens camera, the content produced will be shown in a way that allows your eyes to see from slightly different angles, thus creating an immersive and realistic feel.

Looking back at Fig.4, one can apply both visual experience and visual feeling to image M. Using only visual experience, it is easy to mistake the tilted image M with image N parallel with surface A: the houses stand in the Y-axis and the road extends to the Z-axis. However, because image M is not parallel to surface A, the image has an additional dimension of depth. The viewer's eyes will see the houses, road, and trees on the bottom of the picture more differently than those on top of the picture. So, using visual feeling, the viewer can perceive a sense of the picture extending in the Z-axis, thus creating a sense of realism and an immersive feel. By combing visual experience and visual feeling, the objects in the picture would seem to be perpendicular to surface C, thus giving a sense of 3-dimensionalism.

Results and discussion

To demonstrate the 3D visual effects described in the previous section, we have created a similar experiment using a landscape photo, which will more easily demonstrate the effects of visual experience and visual feeling. By placing image N and image M into the configuration shown in Fig.5. We then created a makeshift window using black paper to prevent any unnecessary interference. After the experiment, everybody thought that image M is indeed more immersive and realistic than image N. We invited 10 volunteers, who were not told what to expect beforehand, and asked them to list the differences between the two pictures. At least 8 of them were confident that image M was more like a 3D image and more immersive.

Fig. 5. The configurations of the image N and image M.

With the design of Project A, we can also get a 3D visual effect from a 2D image. However, a challenge we faced in designing Project Air is distorted images. The image of smartphone screen is bent downwards on both sides referring to Fig. 6. Free form curvature mirrors can only minimize the distortion caused by the concave reflection. To solve the distortion completely, the first reflective mirror should be a convex mirror with a focal distance equal to 60 cm to make the reversed image of convex mirror bent upwards in Fig. 7 and 8.

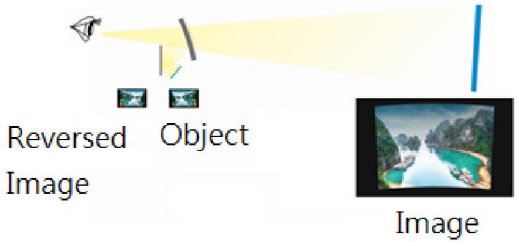

Fig. 6. The image of smartphone screen is bent downwards on both sides.

Once we replace the flat mirror with a convex mirror, the formulas must be adjusted accordingly by merging the convex mirror formulas with the original concave mirror formulas to accurately depict the system, as shown in Fig. 8. The main difference between the two formulas is that the magnification ratio of convex mirrors, xM, is less than 1. The readjusted formula for attaining the magnification ratio is shown below.

$$xM = \left|\frac{xd_i}{xd_0}\right|, m = xM \bullet M$$

Projection distance is calculated using the formula depicted below:

$$d_0 = xd_i + D, \frac{1}{f} = \frac{1}{d_i} + \frac{1}{xd_i + D}$$

The structure described above, once unfolded, can project images in amazing quality. During our initial tests, 10 out of 10 people can easily see the 3D immersive effects.

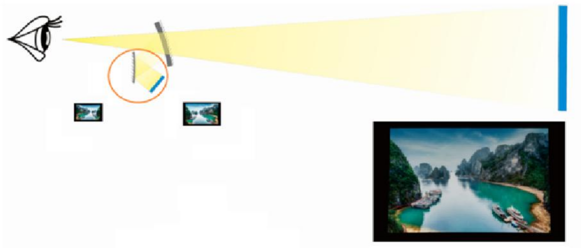

Fig. 7. To solve the distortion completely, the first reflective mirror should be a convex mirror with a focal distance equal to 60 cm to make the reversed image of convex mirror bent upwards.

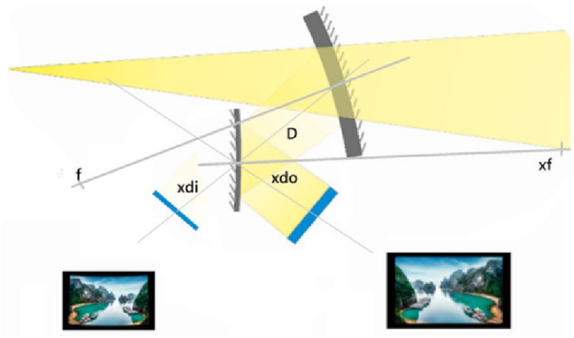

Fig. 8. Replacing the flat mirror with a convex mirror, the formulas must be adjusted accordingly by merging the convex mirror formulas with the original concave mirror formulas to accurately depict the system.

Conclusion

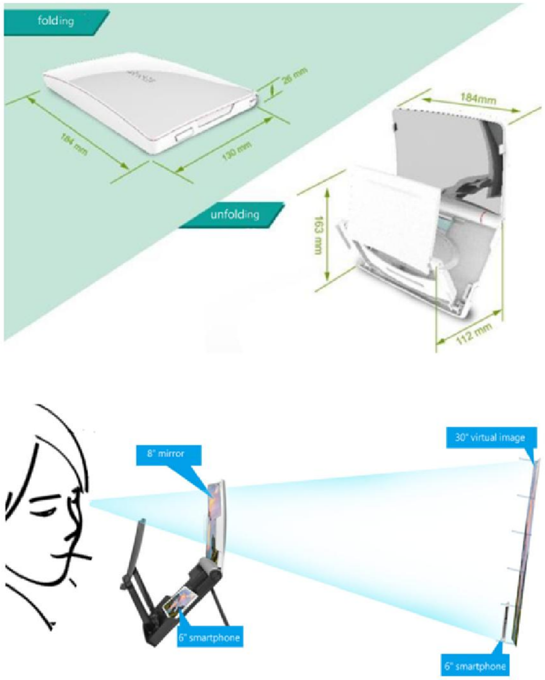

Fig. 9. Using the combination of a convex and a concave mirror with the folding mechanisms.

12/12/2017

In summary, using the combination of a convex and a concave mirror with the folding mechanisms shown in Fig. 9; Project Air can magnify a smartphone's screen up to 5 times (up to 30") and project it over a meter away. Not only will help it reduce the strain and potential damage the smartphone inflicts to the user's eyes, this design can overcome the minimum screen size limitation for 3C products. Using a similar design, we can project a 1.5" smartwatch screen 40cm away and up to 7.5", making it larger than your traditional smartphone. Thus, increasing the chances of smartwatches replacing smartphones in the future. In addition to enlarge image, Project Air also provides 3D visual effect even though the real image is 2D. Many of the test audience even told us there was a significant "3D feel" to the images without us explaining beforehand.

Corresponding author:
Chi-Ting Horng MD, PhD
Department of Ophthalmology, Zuoying Branch of Kaohsiung Armed Forced General Hospital, No.553, Junxiao Rd., Zuoying Dist., Kaohsiung City 813, Taiwan Tell phone: 886-5834845
Email: h56041@gmail.tw

References

1. C.-W. Pan, D. Ramamurthy, S.-M. Saw, "Worldwide prevalence and risk factors for myopia," Ophthalmic Physiol Opt 32, 3-16 (2012).
2. G. Tosini, I. Ferguson, K. Tsubota, "Effects of blue light on the circadian system and eye physiology," Mol. Vis. 22, 61-72 (2016).
3. E. Hecht, Optics, Addison-Wesley, 2002.
4. G. R. Fowles, Intorduction to Modern Optics, Holt, Rinehart and Winston, Inc., 1975.
5. M. Born and E. Wolf, Principles of Optics, Pergamon Press., 1970.
6. M. Katz, Introduction to Geometrical Optics, World Scientific, 2002.