Welcome to the Wonderful World of 3D

How to Create the Parallax Effect

In the July/August issue of Optics & Photonics News, we began this four-part series with an article on the history and principles of three-dimensional imaging. This second installment provides instructions for a series of experiments that will allow you to generate 3D images for yourself by creating the parallax effect.

Barney Johnson, Stereogram, Dice 1, from 3Dwonderstuff.com
This image should appear in 3D when the viewer crosses his or her eyes to overlap two adjacent dice. If this doesn’t work, try crossing your eyes with the page very close to your face and then slowly pulling it away.
The parallax effect enables most people to view 3D images. Parallax refers to how our left and right eyes see the same scene in two different views.

The top figure on the left reviews how the parallax effect generates a 3D illusion. The illustration to the left in the figure shows what a viewer's left and right eyes see when a ball is in front of him or her. The left eye sees the ball to its right, while the right eye sees the same object to its left. The viewer's brain judges the distance to the ball using this information as well as other factors.

The next illustration shows two pictures of the ball drawn on the projection plane behind the ball by extending the lines of sight onto the plane. The view seen from the left eye is projected onto the right-hand side of the projection plane and vice versa.

The light paths between the center-crossing point and both eyes are the same as the light path that would have been created by the actual ball. To the eyes, whether the line started from the object or from the projection plane does not make a difference, as long as the light looks as if it is starting from the object. The eyes perceive the object as if it were at the original location.

However, placing these two ball pictures on the projection plane is not enough to create the illusion that the ball exists off the plane. As shown in the center figure on the left, the viewer sees a picture of two balls side by side simply because each eye sees both pictures of the ball on the projection plane, as indicated by the solid-line traces and the dashed-line traces. Therefore, in order for the ball to appear off the plane, you must find a way to ensure that each eye sees only one picture of the ball by blocking the dashed-line traces.

Try to block only the dashed-line traces and pass the solid-line traces by extending your hands, as illustrated in the figure. You can verify this using ready-made stereoscopic pictures, as shown in the figures on pp. 44 and 46. For the best results, enlarge the figures to letter-paper.
size (8 ½ × 11 inches) for easier viewing. By extending your hands, you will find that the pictures become instantly three-dimensional.

A hands-free way to accomplish this is by wearing a pair of horse blinder glasses, which can be made out of cardboard (see bottom figure on the left). To create a pair, cut the top, bottom and innermost sides of a central square, and make a window by pushing the square open by about 30 degrees—just enough to block the dashed line trace but pass the solid-line trace for each eye. With this projection method, it is important to remember that the picture viewed from the left is placed on the right-hand side. In other words, the pictures have been transposed.

The goal of achieving 3D displays by the parallax effect essentially boils down to finding ways to pass the crisscross path while blocking the parallel path.

The image on the opening page is based on a similar principle. The dice are arranged so that the distance between adjacent dice is short. Thus, crossing your eyes can create the crisscross light path.

[ Experiment 1 ]

What controls the amount of image pop-out?

In the first experiment, you will experience the sensation of a red dot popping out from your laptop computer screen. In order to establish the crisscross path, make yourself a pair of horse blinder glasses out of cardboard. You can enlarge the diagram to 47 cm and use it as a template to cut the cardboard. The other choice is to use the combination of a cellophane sheet with polarizer glasses, as described in Experiment 4.

Draw two red dots, as shown in the figure on the right. Instructions for Photoshop and Paint are given in the table on the right. The dots should be about 3 to 5 mm in diameter. After drawing them, wear the horse blinder glasses and position your head about 30 to 40 cm from the screen.

First, separate \( a \) and \( b \) by about 10 cm. Close your left eye to see if only the red dot \( a \) is seen. Then, close your right eye to see if only the red dot \( b \) is seen. If this is not possible, adjust your distance to the computer screen. Make sure that the amount of the push-out of the square opening of the horse blinder glasses is about 30 degrees. If you have established the crisscross path of the two dots, you will observe the pop-out of the red dot to \( c \).

As you increase the separation between the two dots \( a \) and \( b' \), you will be surprised to experience that the stereoscopic image of the red dot starts popping out of the computer screen and flying toward you. Recognize that the amount of the pop-out of the image increases with the separation of the two points. In addition, if these points are separated beyond the limit of the convergence of your eyes, this effect ceases. After experimenting with this axial movement of the red dot, you are ready to move to the next experiment.
[ Experiment 2 ]

Creating a 3D image from the left and right views of an object

Now we move to a more complex image than a red dot. To observe the 3D effect, you need to combine transposed left and right views. If you have artistic talent, you can draw the left and right views. You can either draw them freehand and scan them into your computer, or draw them directly using a graphics program. If you are less artistically inclined, you can take left and right views of an object using a digital camera. Take a snapshot from the right, step about 30 cm to the left, and take a snapshot of the left view. Load the left and right images into your computer.

A bit of both techniques were used in the figure on the right. The left and right views of the home plate are hand drawn, while those of the ball were fabricated by photographing a baseball from two different camera locations. For simplicity, only the home plate and the baseball are involved in the 3D effect, but you are welcome to make left and right views of the pitcher as well if you want to include him in the 3D effect.

Place the views of your object side-by-side in your image editing program, as shown in the figure. Recall that the images need to be transposed, so the left view is placed on the right side, and the right view is placed on the left. You can retouch or add to the views so that they look more three-dimensional.

To dramatize the 3D effect of the pitcher throwing the baseball toward the home plate, shift the baseball on the left side toward the left with respect to the pitcher, and shift the home plate on the right side toward the right. Shift the home plate in the same manner. However, you should shift the home plate by a larger amount than the baseball because the home plate is protruded toward you more than the baseball.

To observe the 3D effect, wear your horse blinder glasses and position your head as described in Experiment 1. As an even easier viewing alternative, you can use the cellophane and polarizer technique described in Experiment 4.

[ Experiment 3 ]

Encryption

The figure above shows an encrypted stereoscopic pair of maps of the eastern United States. Enlarge the map to letter size and view it with the hand-blocking technique, horse blinder glasses, or the polarized light method from Experiment 4. One name of a place will pop-out toward you. It is the birthplace of President John F. Kennedy.

That particular place name is displaced to the left in the left map and to the right in the right map by just a couple of millimeters. You can make a similar encryption in a letter to your friend by shifting particular words. Or encrypt the image of a particular individual in a group photo.
[Experiment 4]

Converting your laptop computer into a 3D display

In this experiment, you will make a 3D display using polarized light. You will need the following equipment:

1. A source of polarized light such as the liquid crystal display of a laptop computer.

2. Two polarizer sheets, which are used for the polariscope in the figure above and for the eyepieces of the polarizer viewing glasses. A sheet of polarizer can be ordered from an optics company such as Edmund Optics (www.edmundoptics.com; for example, Edmund Optics 2” × 2” Stock No. G47-781).

3. Clear cellophane, 25-micron thick, such as the kind used to wrap gift baskets. The cellophane sold by Lewiscraft (www.lewiscraft.ca) has been found to work well. It is sold under the name “Clear Cello Wrap,” and its SKU number is listed as #17606. Alternatively, you can ask if you can test cellophane samples at a floral shop or craft store prior to purchasing them.

4. A stereoscopic pair of images. You can use an ordinary digital camera to take the stereoscopic pair of images. Take the right picture in the usual manner, and the left by stepping to the left from the spot where the right picture was taken. The amount of camera shift between snapshots will depend somewhat on the scale of the scene being photographed. For the orchid and doll scene in the figure on p. 46, the photographer stepped 30 cm to the left to take the left-view snapshot.

The technique of creating 3D images using polarized light gives you more flexibility in positioning your eyes than the horse blinder glasses. A convenient source of polarized light is a liquid crystal display, such as those used in laptop and desktop computers, camera phones and even camcorders. The light from a liquid crystal display is already linearly polarized.

In the polarized light method, the polarization direction of light from one half of the screen is rotated by 90° from that of the other half of the screen, so that the crisscross path is established by wearing polarizer glasses with eyepiece polarization directions that differ by 90°.

A 25-micron-thick sheet of cellophane, such as the kind normally used for wrapping gift baskets, has been proven to rotate the direction of polarization of light. This cellophane sheet, however, does not work as required unless the sheet is oriented properly with respect to the direction of light polarization from the liquid crystal display.

Cellophane is fabricated by protruding an alkaline viscose solution through a narrow die into an acid bath. Because of the unidirectional strain during the protruding process, cellophane is birefringent—meaning that the refractive index measured by light polarized in one direction is different from that measured by light polarized in the orthogonal direction. This birefringence can be used to rotate the direction of polarization.

It is essential that the direction of the protrusion when the cellophane sheet was fabricated be placed at 45° from the direction of the incident light. If you cannot identify the direction of protrusion by looking at the cellophane sheet, you can perform a simple experiment to determine it by using a homemade polariscope consisting of two polarizer sheets.

3D movies are also made by means of polarized light. Two movie projectors are used to create the effect: One vertically polarizes the picture while the other works horizontally. The projected light is polarized using a polarizing beam splitter.
First, orient the directions of the polarizers to be perpendicular to each other. You’ll know they’re perpendicular when there is practically no transmitted light and the overlap area appears dark. Then, insert the cellophane sheet between the polarized sheets, as shown in the figure. Rotate only the cellophane sheet and observe the variation of the transmitted light. If there is no variation, please try another brand of cellophane because your sample is either the wrong material or the wrong thickness. The orientation of the cellophane sheet that minimizes the light transmission is either the protrusion direction or the direction perpendicular to it. (It doesn’t really matter which, but to simplify the experiment, I will refer to it as the protrusion direction.) Using the edge of the polarizer sheet as a guide, draw a line on the cellophane with a marker to indicate the protrusion direction.

Next, determine the direction of polarization of light from the liquid crystal display by holding one of the polarizers in front of the display and rotating the polarizer to find the maximum transmission. Cover the right half of the liquid crystal display with cellophane oriented with the protrusion marker line at 45° to the direction of light polarization from the liquid crystal display, so that the direction of polarization of the area covered by cellophane is rotated by 90°.

For example, the light from the liquid crystal display of the computer in the figure above is polarized at 45°. The protrusion mark is placed in the vertical direction (90°), which means that light from the cellophane-covered right side is polarized at 135°.

If your computer screen happens to be polarized in the vertical direction (90°), then place the protrusion mark at 135° and the cellophane-covered right half of the screen will become polarized in the horizontal direction (180°).

Next, make your own polarizer glasses. Cut the frames out of cardboard, and insert properly oriented polarizers for the eyepieces. Match the polarizer for the left eye to the right side of the screen, and match the polarizer for the right eye to the left side of the screen.

Now, you will make a preliminary test of your system. Wear your polarizer glasses. Open your left eye and close your right. The right half of the screen should appear bright, and the left half should appear very dark. Conversely, with the left eye closed and right eye open, you should see the left half bright but the right half very dark. It is essential to pass this crisscross test; otherwise, the system will not function.

If you have a problem, recheck the property and orientation of the cellophane sheet. The last step is to display the right and left views of an image side-by-side on your computer screen. Recall that the images need to be transposed, as in the figure above. Wear your polarizer glasses to see the 3D effect.

If you pass the crisscross test, but your brain still cannot fuse the left and right stereoscopic pictures into one 3D image, you are among a minority of people who have poor binocular fusion.

A convenient source of polarized light is a liquid crystal display, such as those used in laptop and desktop computers, camera phones and even camcorders. The light from a liquid crystal display is already linearly polarized.
Direction of light polarization from the camera phone display. In the case of my camera phone, it is placed at 135° + 45° = 180°, namely in the horizontal direction.

Install the polarizer sheet into your glasses in such a way that the left eye can see only the right camera phone image and the right eye, the left image, to establish the crisscross light paths.

You need two camera phones and a pair of properly oriented polarizer glasses. First, determine the direction of light polarization from the liquid crystal display of the camera phone using a polarizer sheet. The direction of the polarization of my camera phone, a Panasonic GD 88, is 135° from the horizontal axis (135° counterclockwise from the x-axis).

Next, paste the cellophane sheet over only one of the camera phone displays—the one that will be placed on your left when you view the received image. The direction of the protrusion axis of the cellophane is placed at 45° from the direction of light polarization from the camera phone display. In the case of my camera phone, it is placed at 135° + 45° = 180°, namely in the horizontal direction.

Install the polarizer sheet into your glasses in such a way that the left eye can see only the right camera phone image and the right eye, the left image, to establish the crisscross light paths. The direction of polarization of my camera phone and the glasses are shown in white arrows in the lower right corner of the figure above.

Now, the preparations have been completed. In the transmitting site, place two cameras side by side spaced 6 to 7 cm apart and press the shutters of both simultaneously. Dial the receiver phones to send the pictures. It is certainly a good idea to examine the 3D images before you send them to the receiver site by covering the cellophane sheet on the right camera phone, crisscrossing your hands, and viewing with the crossed polarized glasses.

In the receiver site, transpose the images by crisscrossing hands, and cover the left phone with the cellophane sheet. Wear the crossed polarized glasses to view the 3D images.

Stay tuned for the third article in this series, which will feature anaglyph experiments.

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