Part III

Geometry and two-dimensional design

Chapter 6

Geometry and the picture plane

The history of geometrical optics is tied intimately to the history of the visual art that pre-dates photography. Look at paintings from the middle ages and they are unlike photographs in many ways. For example, the sizes of forms in the paintings were not necessarily connected in a representational manner, as they are in a typical photograph, to the sizes and distances of objects in the real world. Instead, the size and positioning of forms in a medieval painting often had more to do with what was more or less important (see for example Duby, 1992, chapter 1). It was not until the Renaissance that painters really worked out the details of *linear perspective*, allowing one to duplicate a scene on canvas akin to what would later appear in photographs (Fichner-Rathnus, 1992, pp 333–4).

Photography clearly has much to do with the connection between the three-dimensional (3D) world and two-dimensional (2D) art, for at its most basic level a camera takes rays of light from the 3D world and redirects them to a 2D surface. But the 'fourth dimension' of time is also important. It is now common to see photography as an act of freezing a moment of time, and photographers often take advantage of this. See, for example, the disturbing use of this power in *Execution of Vietcong Prisoner* by Eddie Adams.

A case can be made that the idea that an instantaneous moment of life can be captured with paint on canvas came into its own with the Impressionists, who were very much influenced by then-new photography. In volume 3 of *The Physics and Art of Photography* we revisit this question of the relation between painting and photography.

6.1 From 3D to 2D

Part of the essence of photography is that elements of the inherently 3D world are directed onto a 2D surface. At first glance, one might think that, as with a camera, this is exactly what the human eye does. Rays of light from the world are focused by

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the eye's lens and cornea onto specific locations on the two-dimensional surface of the retina. But it is much more complex than that.

Part of the reason that 2D art works at all is that our brains seem to be specifically structured such that we can easily attach worldly, 3D meaning to patterns on a flat surface. Presumably, this is because the brain must make sense of the essentially 2D information coming from the eye. How the eye/brain does this is extraordinarily complex and only partially understood, but much of the detail has little direct counterpart in the operation of a camera.

For one thing, the image from a camera (or eye) lens literally represents only directions in space, not distances. An *image* is only a 2D representation, and yet we construct a 3D universe out of that image.

This fact is particularly (and painfully) obvious to an astronomer. Take a picture of the night sky, and one sees a pattern of bright dots—stars. But there are an infinite number of possible 3D arrangements of those stars consistent with that same picture. To determine that third dimension of distance requires much additional information that is not available in the photograph alone, and this task is a central preoccupation of astronomers.

But the human brain, in its second-by-second workings, doesn't really operate in this considered, mathematical way. The brain adds its own interpretation to the mix of data coming from the eye; it makes stuff up, in a sense. And so it is possible to take advantage of this fact and trick the brain; the phenomena of *optical illusions* provides evidence for this, and clues to the actual mechanisms at work.

6.2 The human brain's construction of three-dimensional reality

Experiments have shown that the image on the retina of the human eye is very different from what we actually perceive as sight. The human eye in its construction has much in common with a camera; a lens focuses an image onto a surface (the retina) that is sensitive to light. But the similarity ends there. Much is sometimes made of the fact that the image on the retina is, like in a camera, upside down; but that is not such a big deal. Most of 'seeing' is in the brain, not in the eye. Flipping the image right-side up is the least of it.

Some of the research carried out in the 1950s and 1960s by the Russian psychologist Alfred Yarbus provides a good example (Yarbus 1967). Yarbus recorded the eye movements of observers as they performed certain tasks. He found that for even something so simple as looking at a motionless face, the human eye darts around all over the place; see figure 6.1 for an example. It seems that we tend to look at the eyes and mouth a lot, as can be seen from the eye movement trajectories he recorded. If one pointed a video camera at the same face, and moved it according to such a trajectory, the resulting video would likely be unintelligible.

Yet somehow the brain makes sense of this seemingly confusing information coming from the eye. Clearly the brain *constructs* an image from this information, rather than simply recording it. And that image is of a 3D world with objects in it. And what we 'see' not only ignores much of the irrelevant information coming from the retina, it also includes elements not even present in that stimulus; the brain

Figure 6.1. An illustration tracking the eye movements of a subject looking at a photograph of a face, work pioneered by the Russian psychologist Alfred Yarbus. Even when looking at something so simple, the human eye is constantly darting about. Yet we perceive a motionless image (graphic: SpoonSpa, Simon Viktória, CC BY 2.0 Generic).

makes stuff up. And this means that *we can attach meaning to even the simplest marks on a flat surface*. For painters and photographers, who make images on a flat surface, this is a lucky break! A photograph is just a flat piece of paper with marks on it. But we can see the world when we look at a good one.

6.3 Linear perspective and the *Camera Obscura*

Which came first, the camera or the light sensitive material that goes in the camera to make the photograph? It is a surprise to most people that the correct answer is the camera, which preceded the invention of photo-sensitive materials by a couple of hundred years. But when one realizes that the word *camera* is simply the Latin word for an enclosure, then maybe it is not so strange. Long before cameras were used to record images, they were used to view them. The *camera obscura* is simply a 'dark box.'

It has been known for centuries that one can use geometry to produce images. Place a small hole in one side of a dark box, and each ray of light coming from objects in the world will be restricted by the hole to only one spot on the opposite side of the box. See figure 8.1. Thus, an image of the outside world is automatically reconstructed on the inside of the box. This basic idea underlies both the ancient camera obscura, and the modern pinhole camera we discuss in detail in chapter 8.

A glass lens allows one to (among other things) brighten this otherwise dim image, and this too has been known for centuries, at least since the 1500s. When light-sensitive materials were invented in the 1800s, the already-existing camera obscura developed into the photographic camera (Marien, 2002, pp 3–7).

One simple way to view the image in a camera obscura is to make the dark box very large, and put yourself inside. The photographer Abelardo Morell has been doing this with great success. He uses paint to black out the windows of a room with a view, and then scratches a small hole in the paint. An upside down image of the outside world appears on the opposite wall. This is, in effect, a giant pinhole camera with the photographer inside. Very little light enters through the small hole, and so the image is very dim—barely visible to the naked eye. He photographs this image with a separate camera, set up inside the room, using a long time exposure to make up for the dim light.

A not-very-impressive example of this same technique is shown in figure 6.2. The darkened room of my physics classroom was photographed with a long time exposure. The image on the wall is from a small hole in the blinds opposite. The photograph has been inverted so the camera obscura image, of the grounds outside the lab, is upright.

The camera obscura and related optical and sighting devices were instrumental in the discovery of mathematical rules for laying out a realistic perspective in paintings, what art historians call *linear* or *mathematical perspective*. Some have speculated (the thesis is still controversial) that some of the Flemmish painters of the 17th century (Vermeer in particular) used a camera obscura to properly locate the details in their paintings (Steadman 2001). In 15th century Italy, Filippo Brunelleschi performed experiments with a sighting device much like a camera obscura in order to work out the first formal methods for incorporating precise linear perspective into paintings and drawings.

Figure 6.2. My physics classroom photographed from the inside. A small hole in the blinds produced the image of what is outside the lab. The picture has been turned upside down, and so the room appears inverted but the camera obscura image is upright.

6.4 The picture plane

Photographs are often *representational*; forms in the photograph are meant to directly represent things in the real world. But as is the case for all 2D art, there is more to it than that. An important element is the *picture plane–the flat plane representing the 2D surface of the photograph itself*. While this concept of the picture plane *as a physical surface* is of crucial importance for painting, it is sometimes downplayed or ignored in photography, which often strives to be purely representational.

This can be seen in the way many photographs are displayed. A mat is used to overlap the image area of the print. And so the opening in the mat appears as a window, with the picture behind. The intent seems to be to hide the fact that one is looking at a piece of paper; only the representation of the image matters.

Many photographers however, aligning themselves somewhat more with the history of painting and the early history of photography, go out of their way to draw attention to the picture plane. One method is to use alternative printing processes that introduce their own elements in the form of random detail and textures (Rexer 2002). We will explore some of these printing processes in more detail in volume 3 of *The Physics and Art of Photography*. Often the goal here is similar to that of traditional art printmaking. The image is the same, but each print is slightly different, and thus unique, due to the handmade process. And the more-interesting and less-uniform surface of the paper itself is often evident. And so it is not just an image; it is an image on a flat piece of interesting paper, and the paper is the picture plane.

But the negative process of film photography allows for another interpretation of the picture plane. One does not normally view a photographic negative directly; rather one looks at a positive print made from it. *But the negative also represents a flat plane, and it is what was actually inside the camera at the moment the photograph was taken.*

Thus in negative-based film photography, we actually have a possibility for two picture planes: the surface of the print itself, and the surface of the negative that was used to make the print. Details in each can draw attention to these two flat surfaces, forming an additional element in the formal construction of the picture. This is an especially important point in the modern age, where many pictures never exist as a physical print. Thus the picture may be an image on a large computer screen or on a tiny smart phone, depending on who is looking at the picture. Where then is the picture plane? Is the concept still meaningful when no *physical* image surface exists?

Figure 6.3 shows an image made from an old type of Polaroid large-format negative film. This type of film made its own instant print and a high-quality instant negative, that could then be printed in the darkroom. No darkroom was needed to produce the negative itself; one just needed to clear off the developer goo, in daylight in the field, with a simple sodium sulfite solution (often carried around by the photographer in a bucket).

In this case, I allowed the goo to remain on the negative, and in fact rubbed it in the dirt to make it even more yucky. I then allowed the negative to dry without

Figure 6.3. *Proof of Life on Earth*, John Beaver 2008. This photograph was scanned from an intentionally-damaged negative, thus making evident the flat surface of the negative itself. This surface detail introduces a picture plane *into the image itself*, independently of how it is displayed.

washing it. The result was a bad negative that would have been difficult, if not impossible, to print in a traditional darkroom. But it was possible to scan it with a high-quality scanner, and then use digital techniques to reverse it to a printable positive image.

The result is that the surface of the negative is introduced as a picture plane, independent of the manner in which the image is printed or displayed. In this particular case the flat plane of the negative plays off of the seemingly-curved plane of the table introduced by the distortion and vignetting of the particular lens used.

In the chapters that follow we explore this 2D nature of photography, and how it relates to our 3D world. We will see that even a virtual image that never exists as a physical object still has abstract relations between the parts of its 2D 'surface.' In volume 3 of *The Physics and Art of Photography* we revisit some of these ideas in consideration of the physical processes by which light from the world interacts with, and changes, a flat surface in order to form an image. And we explore some methods by which nature can have its own say in the making of photographic art, in ways that are only partially under the control of the artist.

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