(i.e., short focal length) results in a small image and a large viewing angle, just as occurs when a wide-angle lens is used, while increasing the "focal length" f results in a larger image and a smaller viewing angle, just as occurs when a telephoto lens is used. The negative sign in Eqn. (2.1) means that the projected image is flipped in the horizontal and vertical directions and rotated by 180°. Equation (2.1) describes what is commonly known today as the perspective transformation.[1] Important properties of this theoretical model are that straight lines in 3D space always appear straight in 2D projections and that circles appear as ellipses.

2.2.2 The "Thin" Lens

While the simple geometry of the pinhole camera makes it useful for understanding its basic principles, it is never really used in practice. One of the problems with the pinhole camera is that it requires a very small opening to produce a sharp image. This in turn reduces the amount of light passed through and thus leads to extremely long exposure times. In reality, glass lenses or systems of optical lenses are used whose optical properties are greatly superior in many aspects but of course are also much more complex. Instead we can make our model more realistic, without unduly increasing its complexity, by replacing the pinhole with a "thin lens" as in Fig. 2.3. In this model, the lens is assumed to be symmetric and infinitely thin, such that all light rays passing through it cross through a virtual plane in the middle of the lens. The resulting image geometry is the same as that of the pinhole camera. This model is not sufficiently complex to encompass the physical details of actual lens systems, such as geometrical distortions and the distinct refraction properties of different colors. So while this simple model suffices for our purposes (that is, understanding the mechanics of image acquisition), much more detailed models that incorporate these additional complexities can be found in the literature (see, for example, [59]).

2.2.3 Going Digital

What is projected on the image plane of our camera is essentially a two-dimensional, time-dependent, continuous distribution of light energy. In order to convert this image into a digital image on our computer, three main steps are necessary:

1. The continuous light distribution must be spatially sampled.
2. This resulting function must then be sampled in the time domain to create a single image.
3. Finally, the resulting values must be quantized to a finite range of integers so that they are representable within the computer.

[1] It is hard to imagine today that the rules of perspective geometry, while known to the ancient mathematicians, were only rediscovered in 1430 by the Renaissance painter Brunelleschi.