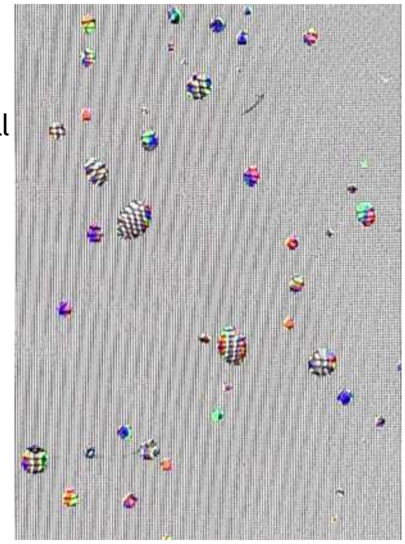
Creating Digital Images



The best way to understand how **digital images** are created is to look at the screen of any modern device with a magnifying glass. You can also place a single drop of water on the lit screen to magnify it. If you look closely, you will see that the image is made up of very small squares called **pixels** (see the image to the right). If you were to zoom in on a pixel, you would see three dots inside: one blue, one red, and one green. These dots are responsible for the wide range of colors we can see on our screens. The more pixels your device's display has, the better the definition of the image that you see.

A digital image is a collection of pixels. To re-create an image, we need to know the **brightness** and **color** of each pixel, and where they go in the image. A digital image file is just a collection of numbers--0's and 1's--in which each number represents the color and brightness of a pixel.

For simplicity, let's first consider a black-and-white image to explore how our devices can tell which brightness goes in each pixel of an image. The brightness of each pixel is encoded using these binary digits, also known as **bits**, and each bit tells the device to turn a particular switch on or off. In a simple 1-bit system, each pixel can either be on (represented by 1) or off (represented by 0):

Switch	Binary code	Color displayed in the pixel
off	0	Black
on	1	White

How can we create different values using this **binary code**? The answer can be found in the number of bits a device uses: the more bits, and thus the more possible values per pixel, the more brightnesses it can be set to. If we increase the number of bits to 2, now each pixel can have 4 different brightnesses ($2^2 = 4$):

Switch 1	Switch 2	Binary code	Color displayed in the pixel

off	off	0 0	Black
off	on	0 1	Dark gray
on	off	1 0	Light gray
on	on	1 1	White

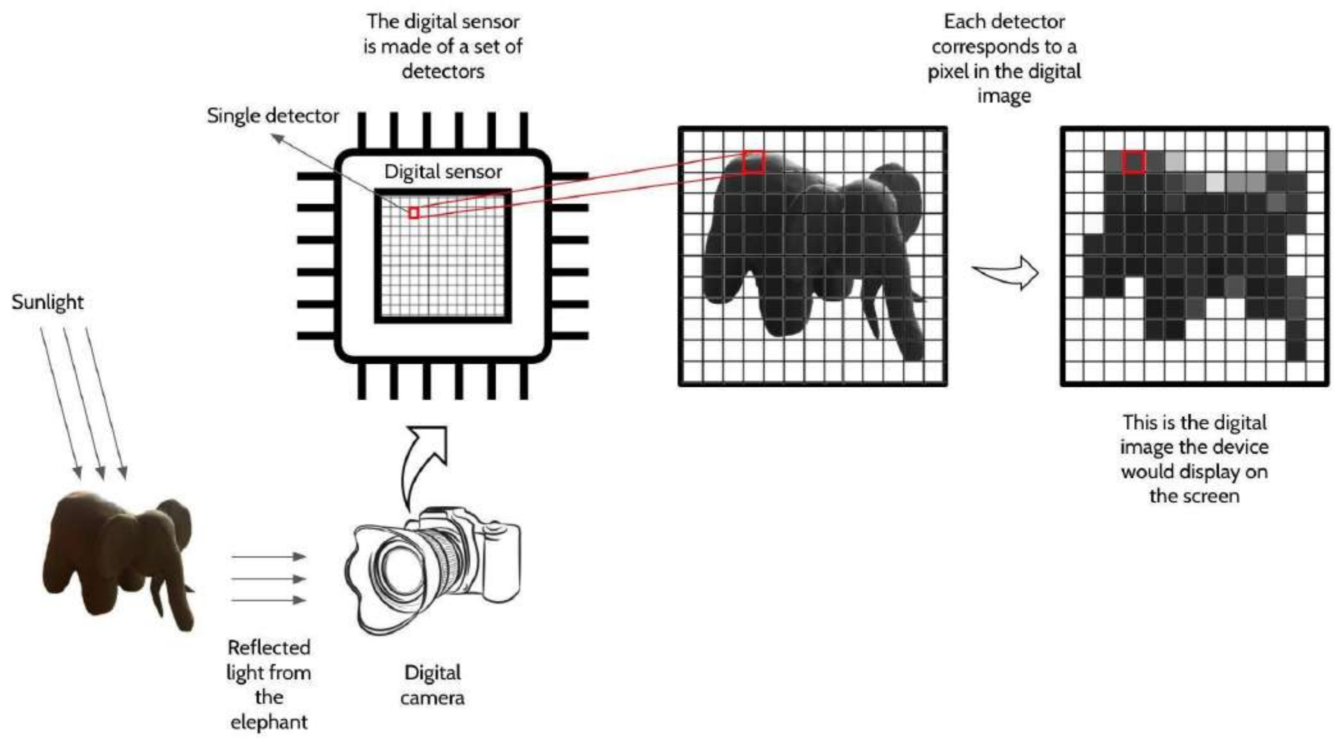
If the device used 3 bits, it would have 8 different value possibilities ($2^3 = 8$), and 64 gray possibilities if it used 4 bits. Each additional bit the device can use increases the number of gray possibilities exponentially.

Colors are created in a similar way. Every color can be made through a combination of red, blue, and green light. On a color screen, each pixel is made of those three lights (red, blue, and green). Each pixel is sent 3 values, one for each color. Many modern devices use 8 bits of information for each color, giving each color 256 brightness values ($2^8 = 256$). Combining these brightness options of the three-color pixel can display 16.7 million different colors.

The binary code tells each pixel what brightnesses to use, producing the image displayed in each pixel of the device's screen. The more bits a device uses, the more values it can display in a given pixel, and the higher the quality and definition of the image is. However, the more bits a device uses, the more processing power it requires, and the more memory storage it needs to save such images.

How do digital cameras create a new digital image?

Digital cameras and scanners use light **sensors** to capture digital images. These sensors are made up of sets of many individual light **detectors** whose function is to convert light into electrical flow. In the image below, the digital sensor has 13 rows and 13 columns of light detectors, which add up to 169 individual detectors in the sensor. Each detector corresponds to a pixel that will be part of the picture.



Alexey_Marcov, Pixabay

When we take a digital picture of an object or a scan of a document, the EM radiation--specifically, **visible light**--that is reflected off of the object reaches the camera's digital sensor. There, each detector receives different amounts of EM radiation, depending on how much of the reflected light reaches it. These detectors are designed to store electrons.

Remember from the photon model of EM radiation that the higher the number of photons passing through a material, the higher the chance that electrons in that material will get knocked out of it? In digital cameras and scanners, sensors can quantify the number of **ejected electrons**, and a detector uses this value to determine the color that corresponds to that particular pixel. For example, if none of the electrons were knocked out, the detector would interpret this as total darkness, assigning a digital value of 0, that would result in a black pixel on the screen.