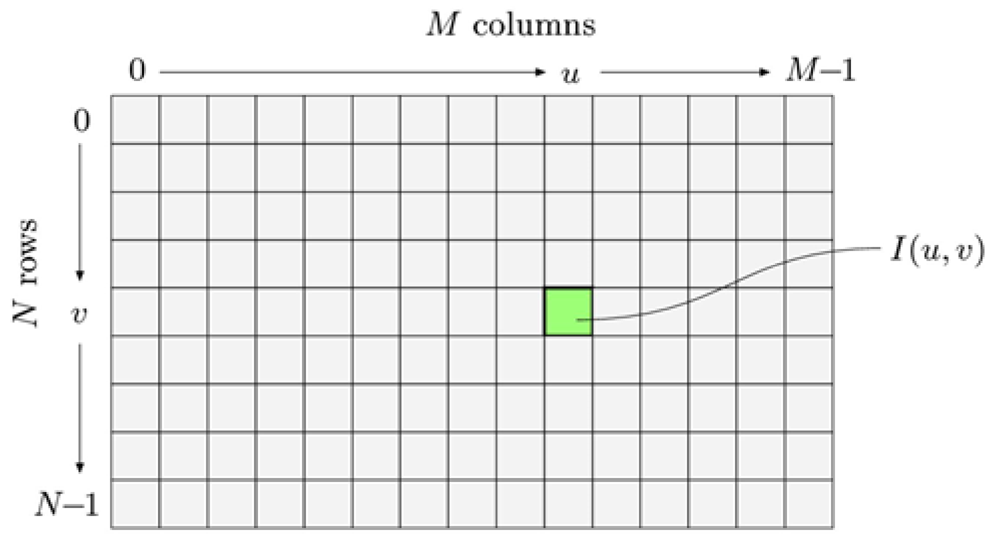
Graphics and Image Data Representation

The image data structure is a 2D array of pixel values as shown in Figure below.

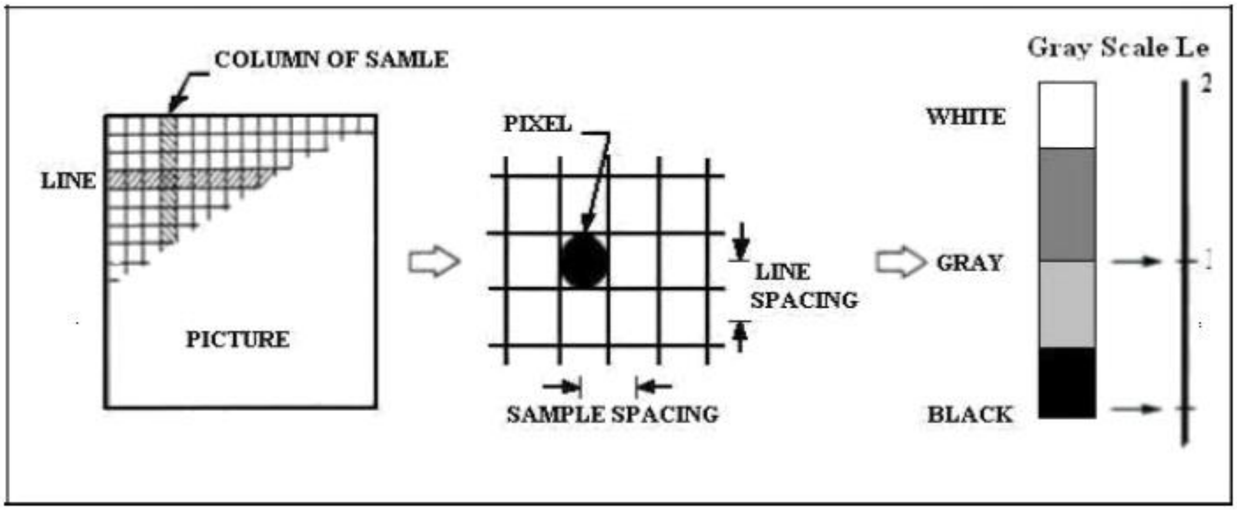


1. Digital Images

An image must be converted to numerical form before processing. This conversion process is called digitization, and a common form is illustrated in Figure (1). The image is divided into small regions called ***picture elements***, or ***pixel*** for short. The most common subdivision scheme is the rectangular sampling grid shown in Figure (1). The image is divided into horizontal lines made up of adjacent pixels.

At each pixel location, the image brightness are sampled and quantized. This step generates an integer at each pixel representing the brightness or darkness of the image at that point. When this has been done for all pixels, the image is represented by a rectangular array of integer. Each pixel has a location or address (Line or row number and sample or column number) and an integer value called gray level. This array of digital data is now a candidate for computer processing.

A digital image is a numeric representation of a two-dimensional image. Depending on whether the image resolution is fixed. The term "digital image" usually refers to **raster images or bitmapped images**. ***Digital Image*** as a sampled, quantized function of two dimensions *f(x,y)* which has been generated by optical means, sampled in an equally spaced rectangular grid pattern, and quantized in equal intervals of gray levels.



Figure(1) *Digitizing an Image*

Thus a digital image is now a two-dimensional rectangular array of quantized sample value.

A digital image consists of many picture elements, termed pixels. The number of pixels determine the quality of the image (resolution).

Image Representation (Data Structures bitmap representation)

As we know, the human visual system receives an input image as a collection of spatially distributed light energy; this form is called an optical image. Optical images are the types we deal with every day - cameras capture them, monitors display them, and we see them. We know that these optical images are represented as video information in the form of analog electrical signals and have seen how these are sampled to generate the digital image *f(x,y)*.

The digital image *f(x,y)* is represented as a two-dimensional array of data, where each pixel value corresponds to the brightness of the image at the point *(x,y)*.

In linear algebra terms, a two-dimensional array like our image model *f(x,y)* is referred to as a matrix, and one row (or column) is called a vector. This image model is for monochrome (one-color, this is what we normally refer to as black and white) image data, we also have other types of image data that require extensions or modifications to this model.

Image Digitalization

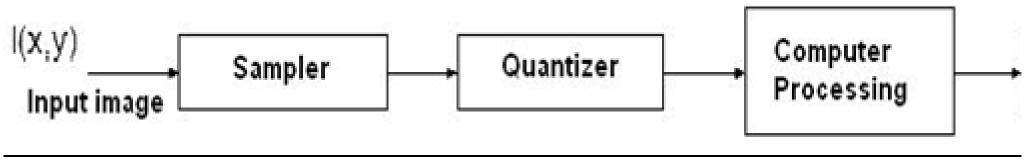
Typical image processing scenario

The image is represented by a function of two continuous variables, spatial coordinates (x, y).

The first function is ***sampling***: we sample the continuous image signal (discretization of the spatial coordinates).

The result is then injected into the ***Quantization*** function: for a monochrome image, we often choose 256 luminance levels.

The image is now digitalized, so we can apply the required image processing, which could be binarization, contrast enhancement, etc.

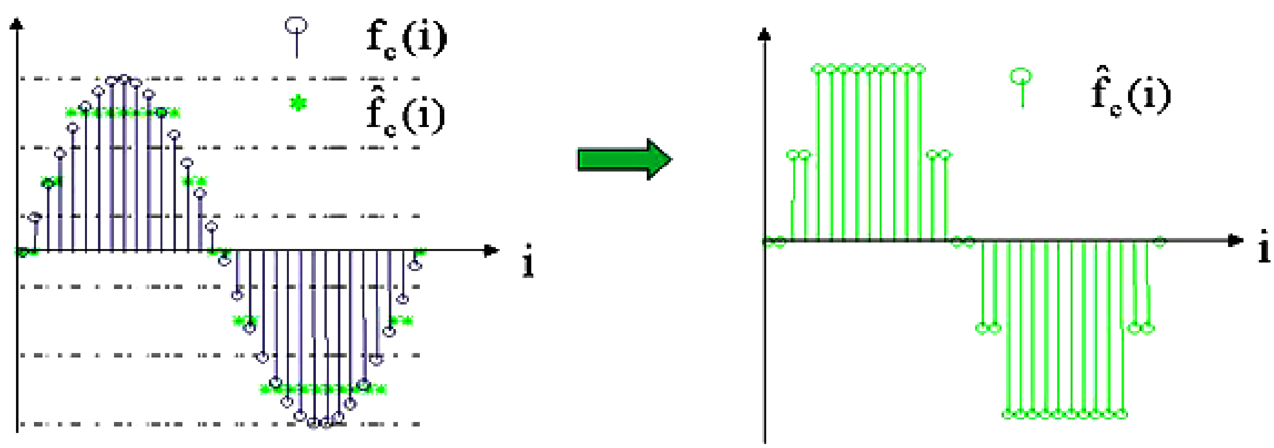


Hence, in order to create an image which is digital, we need to covert continuous data into digital form. There are two steps in which it is done:

1- Sampling

2- Quantization

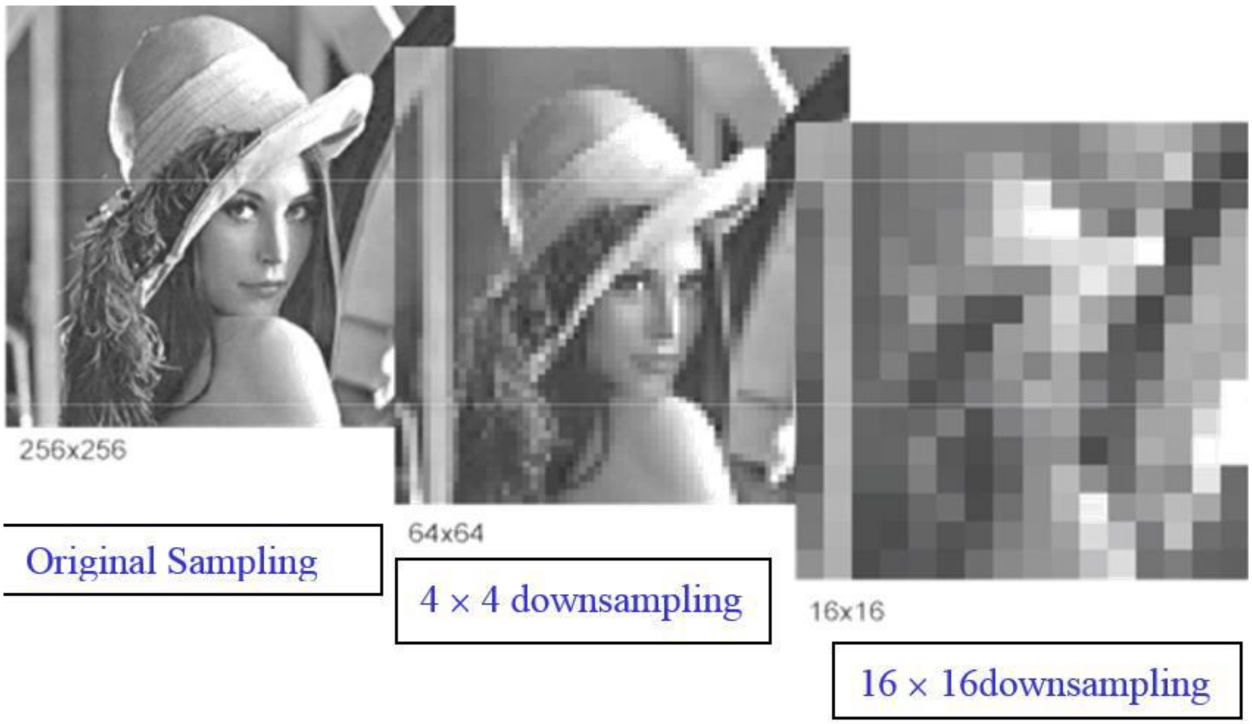
The sampling rate determines the spatial resolution of the digitized image, while the quantization level determines the number of gray levels in the digitized image. A magnitude of the sampled image is expressed as a digital value in image processing. The transition between continuous values of the image function and its digital equivalent is called quantization.



The number of quantization levels should be high enough for human perception of fine shading details in the image. The occurrence of false contours is the main problem in an image which has been quantized with insufficient brightness levels.

1. Sampling (represents => resolution)

The process of creating a digital image from the date acquired by a camera or some other kind of imaging instrument, requires a two-dimensional pattern to represent the measurements (light intensity or color) that are made in the form of an image numerically.



Examples: Image Sampling

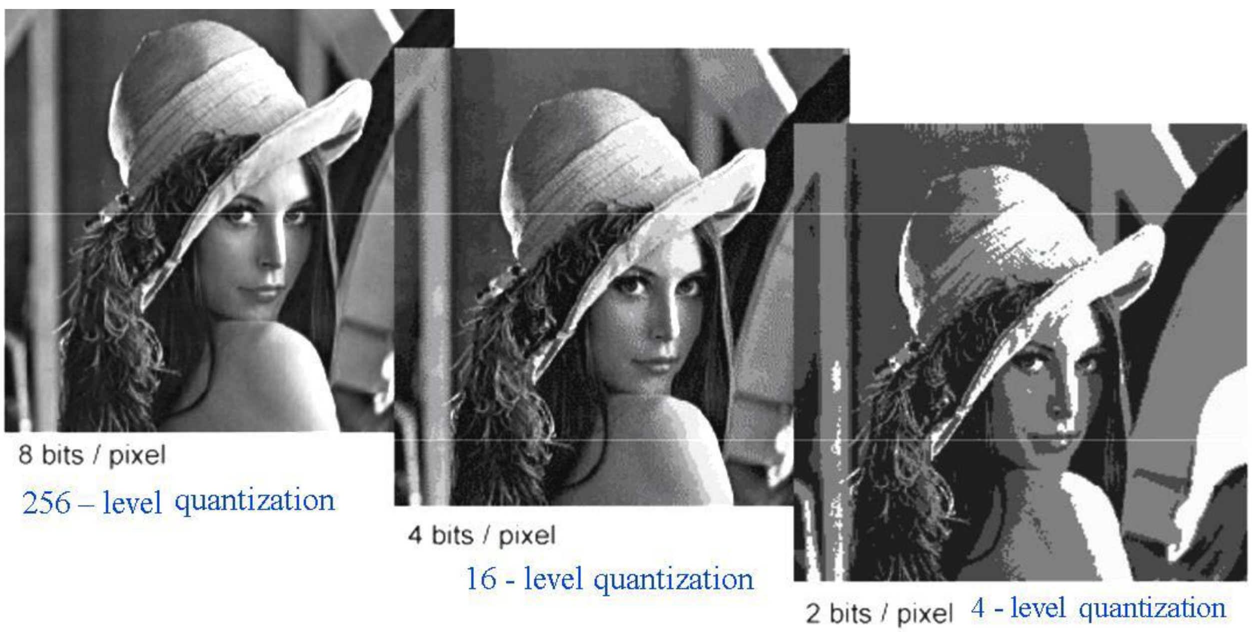
In this figure, we have represented the image "Lena" sampled with two different sampling structures. The image on the left is the reference image (spatial dimensions: (256*256) pixels). The second image is sampled with a sampling frequency four times lower for each of the two spatial dimensions. This means it is (64*64) pixels. For display purposes, it has been brought to the same size as the original using a zoom. This is in fact an interpolation of zero- order (each pixel is duplicated 4*4 times, so that on the screen it displays a square of (4*4) identical pixels).

Sampling: is a process of measuring the value of the image function *f (x, y)* at discrete ***intervals in space***. Each sample corresponds to a small square area of the image, known as a pixel. A digital image is a two-dimensional array of these pixels. Pixels are indexed by *x* and *y* coordinates, with *x* and *y* taking integer values.

2. Quantization

It is usual to digitize the value of the image function *f (x, y)* in addition to its spatial coordinates. This process of quantization involves replacing a continuously varying *f (x, y)* with a discrete set of quantization levels. The accuracy with which variations in *f (x, y)* are represented is determined by The number of quantization levels that we use: the more levels we use, the better the approximation.

Quantization: is the representation of the brightness of each pixel by an integer value. Since digital computer process number, it is necessary to reduce the continuous measurement value of discrete units and represent them by an integer number.



Quantization of an image

This illustration shows examples of a quantization carried out on the image :

For the image on the left: quantization is followed by a natural binary coding with 8 bits per pixel. There are $2^8 = 256$ reconstruction levels to represent the magnitude of each pixel. It is the typical case of a monochrome image (only in gray scales).

For the middle image: quantization is carried out with a 4 bits per pixel coding, giving $2^4 = 16$ reconstruction levels. Contours are well rendered but textures are imprecise in some cases. These are areas in the signal with a weak spatial variation, which suffer more visually due to the appearance of false contours (loss on the face and the shoulder).

For the image on the right: quantization is carried out with a 2 bits per pixel coding, so we have $2^2 = 4$ reconstruction levels. The deterioration seen on the previous image is even more flagrant here.

Spatial resolution and quantization

What is size of the image? And what is a resolution?

Resolution = width x height

Image Size = width x height x No. of bit per pixel

Quantization = Number of bits per pixel (***Quantization***)

Spatial resolution can be defined as the smallest discernible detail in an image. In short, what spatial resolution refers to is that we cannot compare two different types of images to see that which one is clear or which one is not. If we have to compare the two images, to see which one is more clear or which has a more spatial resolution, we have to compare two images of the ***same size***.

Spatial resolution is determined by the ***sampling process***. The spatial resolution of a digital image reflects the amount of details that one can see in the image (i.e. the ratio of pixel "area" to the area of the image display). If an image is spatially sampled at × pixels, then the larger × the finer the observed details. Or in other way we can define spatial resolution as the number of independent pixels per inch (PPI).

Effect of reducing the spatial resolution

Decreasing spatial resolution of a digital image, within the same area, may result in what is known as *checkerboard pattern*. Also image details are lost when the spatial resolution is reduced.

To demonstrate the checkerboard pattern effect, we subsample the 1024×1024 image shown in Figure (1) to obtain the image of size 512×512 pixels. The 512×512 is then subsampled to 256×256 image, and so on until 32×32 image. The subsampling process means deleting the appropriate number of rows and columns from the original image. The number of allowed gray levels ***was kept*** at 256 in all the images.

Figure : A 1024×1024, 8-bit image Subsampled down to size32×32 pixels.

To see the effects resulting from the reduction in the number of samples, we bring all the subsampled images up to size 1024×1024 by row and column pixel replication. The resulted images are shown in Figure.

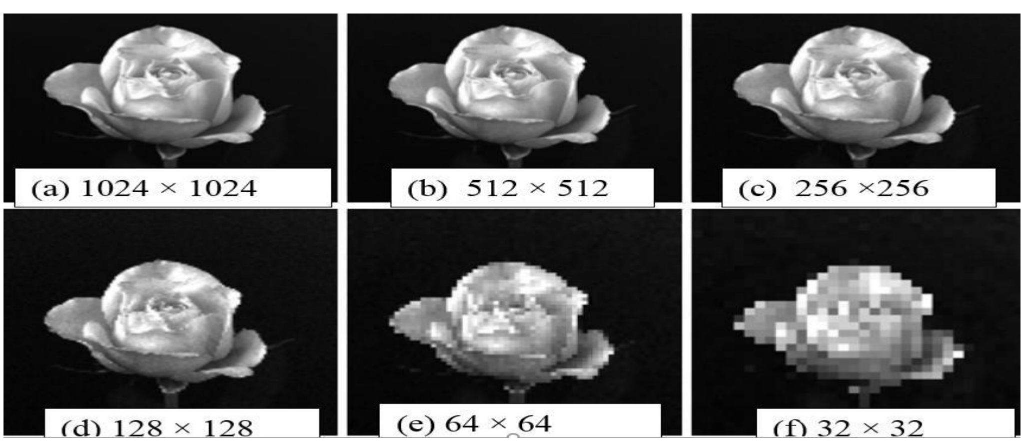


Figure 2. the effects of resulting from the reduction in the number of samples. All images have 8 – bits.

Compare Figure 2(a) with the 512×512 image in Figure 2(b), we find that the level of detail lost is simply too fine to be seen on the printed page at the scale in which these images are shown. Next, the 256×256 image in Figure 2(c) shows a very slight fine checkerboard pattern in the borders between flower petals and the black background. A slightly more pronounced graininess throughout the image also is beginning to appear. These effects are much more visible in the 128×128 image in Figure 2(d), and they become pronounced in the 64×64 and 32×32 images in Figures 2(e) and (f), respectively.