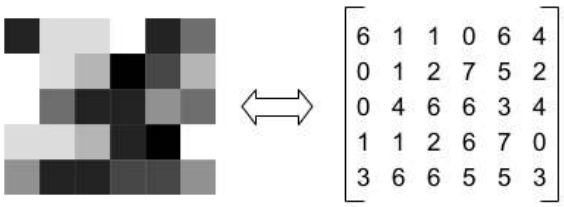
Image Representation and Interpolation

Image Representation

What is an Image to the Computer?

- Images are represented as matrices of values. These values can be any data type
- For Grayscale images, any value of (x,y) in the matrix has a value between 0-255(usually).
  - The Number of grayscale levels is 2^n.
  - We can also come up with our own values for intensities. Say we want to represent an image with 3 colors only, we will only need 3 values instead of 256.
  - This is an example of a simple grayscale image and its representation :



$$\begin{bmatrix} 6 & 1 & 1 & 0 & 6 & 4 \\ 0 & 1 & 2 & 7 & 5 & 2 \\ 0 & 4 & 6 & 6 & 3 & 4 \\ 1 & 1 & 2 & 6 & 7 & 0 \\ 3 & 6 & 6 & 5 & 5 & 3 \end{bmatrix}$$

- For colored images, any value of (x,y) in the matrix is a vector of red,green,and blue, each with a value between 0-255(usually).
- Intensity Level Resolution : Number of intensity levels used to represent the image
  - The higher the intensity levels used, the finer level of detail.
  - Intensity Level Resolution is given in terms of the number of bits needed to store every intensity level.
- The Number of bits required to store a digitized image is :

> M*N*k

or

> (x*y*Intensity Level Resolution)

Noise Level

Noise is the grainy texture pattern in images. This is effected by multiple factors such as ISO, Blur, contrast, etc. We must be mindful of what might cause it and try to reduce it to an acceptable level for our use. Its **not** a measured value, but rather a phenomenon in imagery.

Image Properties

- Resolution : Resolution is how much detail we can have in an image. It depends on sampling and gray level.
  - The Higher the *Sampling Rate* and the larger the grayscale value domain, the better the approximation of the digitized image is from the original.
  - The more the quantization levels, the larger the size of the image.
  - Key Questions to ask when determining resolution :
  - Does the image look aesthetically pleasing?
  - Can you see what you need to see in the image?
- Spatial Resolution is determined by how fine/coarse the sampling that was carried out is. It Is the measure of the smallest discernible detail in an image.

    - A Widely used definition of image resolution is the largest number of discernible line pairs per unit distance
    - Dots per unit distance is a measure of image resolution used commonly in printing and publishing. A Common unit is **Dots per Inch**(DPI)
    - We can also measure resolution using a pair of values representing how many pixels there are in a row and how many pixels there are in a column.

- Saturation : The Value beyond which all intensity levels are clipped (changed to the same level).
- Image File Format : There are many image file formats(gif,png,jpeg). They Each have their own advantages and disadvantages.

Relationship between Pixels

A Pixel at (x,y) has 4 neighbors : (x+1,y), (x-1,y), (x,y+1), (x,y-1).
This set is denoted by N4(p). The four diagonal neighbors of P is the set : (x+1,y+1), (x-1,y+1), (x=1,y+1), (x-1,y-1). this is denoted as ND(p).

All Neighbors of a pixel are 1 unit distance away. Some neighbors of p might lie outside the image. In that case we may take an average or substitute the existing neighbors in calculations.

Adjacency

Let V be the set of intensity values used to refer to adjacency. Adjacency is the set of pixels that are neighbors with an intensity belonging to V .

There are 3 types of adjacency :

- 4-Adjacency: The 2 pixels q,p with values from v are adjacent if q is in the set N4(p).
- 8-Adjacency: The 2 pixels q,p with values from v are adjacent if q is in the set N8(p).
- m-Adjacency: A mixed approach to remove any ambiguities when 8-adjacency is used, the 2 pixels q,p with values from v are adjacent if
    - q is in the set N4(p) OR
    - q is in ND(p) and N4(p) ∩ N4(q).

The boundary of finite regions forms a closed path. Edges are formed from pixels with derivative values that exceed a preset threshold. THis, the idea of an edge is a local concept that is based on **intensity level discontinuity at a point** .

In layman terms, adjacency = paths.

Distance

Distance between pixels is measured using Euclidean Distance. This is the distance in unit length from pixel to pixel. it is given by the equation

> ((x1-x2)^2 + (y1-y2)^2)^(1/2)

Another measure is the City-Block Distance, which is the number of pixels we travel between p an q. It is given by

> |x1-x2| + |y1-y2|

another measure is the Chebyshev Distance. Which is a current subject of research.

Mathematical Tools in Digital Image Processing

Since an image is a matrix of intensities, any operation involving one or more images is carried out on a *pixel-by-pixel* basis. We mostly used *array products* rather than *matrix products* when doing image processing. For example, the array product of adding 2 images is called *superimposing* them, and results in an image which is composed of them both.

Image Interpolation

Image interpolation is the use of known data to estimate values at unknown location. it is an important tool in zooming, shrinking, rotation , and geometric connections.

Some Simple Interpolation Techniques

After the matrix with the new size is created, the missing intensities are filled by a few techniques. This is often used when shrinking or zooming an image, some examples of these techniques are :

- Nearest Neighbor : Assigns each new location the intensity of its nearest neighbor in the original image.
  - Simple.
  - Quick.
  - However, generates distortion of straight edges. This is called **pixelization**.
  - Not used frequently.
- Bilinear : Use the four nearest pixels to estimate the intensity of the new location. This method is described in detail here.
- Bicubic : Use the nearest sixteen neighbors of a point to determine its intensity. Bicubic interpolation is described in detail here.