Image Processing

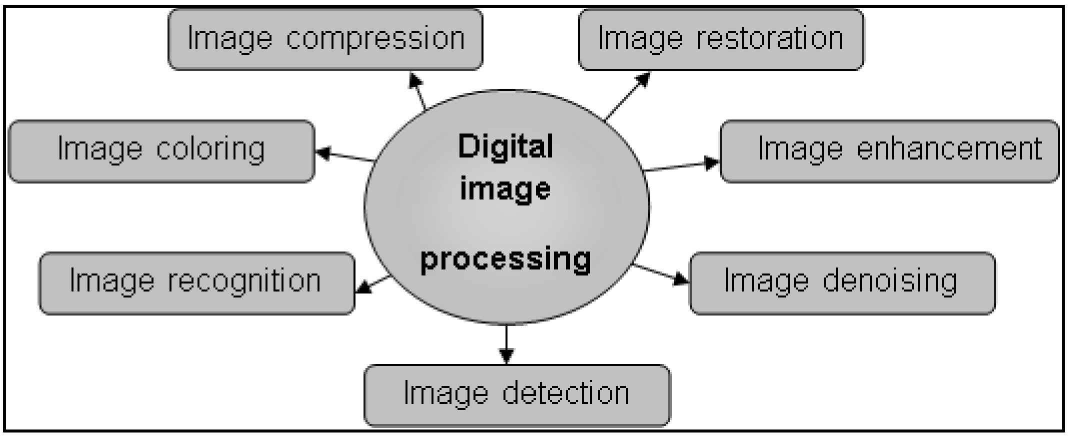
The visual experience is the principal way that humans sense and communicate with their world. A visual beings and images are being made increasing available in electronic digital format via digital cameras, the internet, and hand-held devices with large-format screens. With much of the technology being introduced to the consumer marketplace being rather new, digital image processing remains a “hot” topic and promises to be one for a very long time. of course, digital image processing has been around for quite a while, and indeed, methods pervade nearly every branch of science and engineering. One only has to view the latest space telescope images or read about the newest medical image modality to be aware of this.

Digital Image Processing

Digital image processing is a high growth sector fed by the rapidly falling costs of the hardware (computers, scanners, digital cameras, etc.) and the availability of quality image processing software. Extracting information about the content of the image is part from the aim of image processing. For example examining a blood sample under a microscope to automatically count the number of white blood cells or examining an image of a road scene to pick out the number and type of road signs present. These applications generally require more advanced techniques such as image segmentation followed by pattern recognition.

Image Processing Application

The digital image processing Refer to the operations that be applied on the information of the digital image such as (analysis , transformation , enhancement , ….., etc.).
The digital image processing is a general term for a wide range of techniques that exists for manipulating and modifying images in various ways. The following figure represent some Applications of digital image processing.



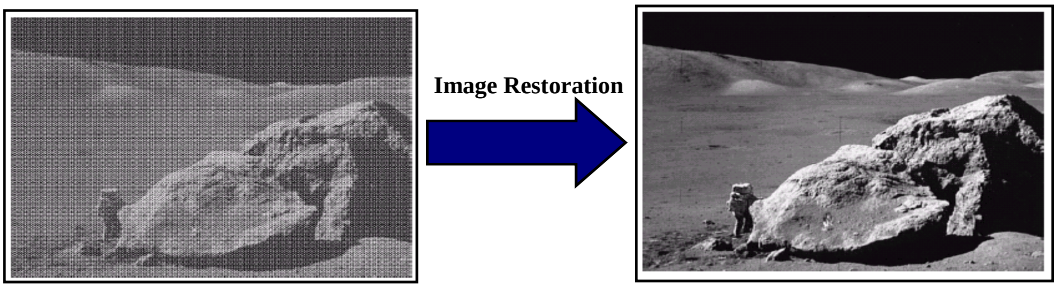
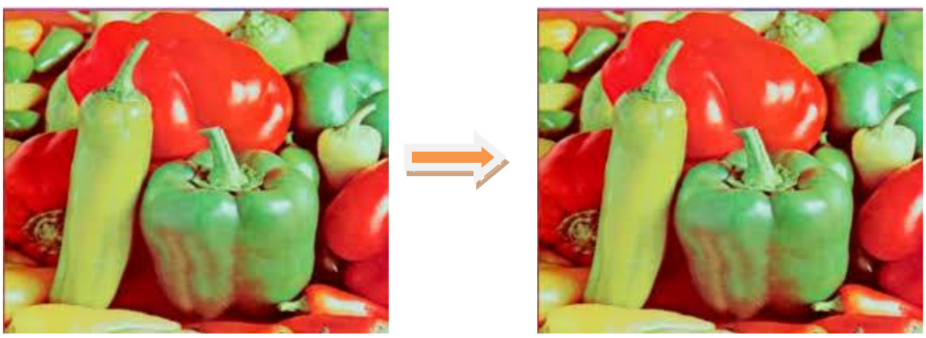


Image Enhancement with Different level of contrast

cameraman with noisy image and Denoising Image



Original Compression 27:1

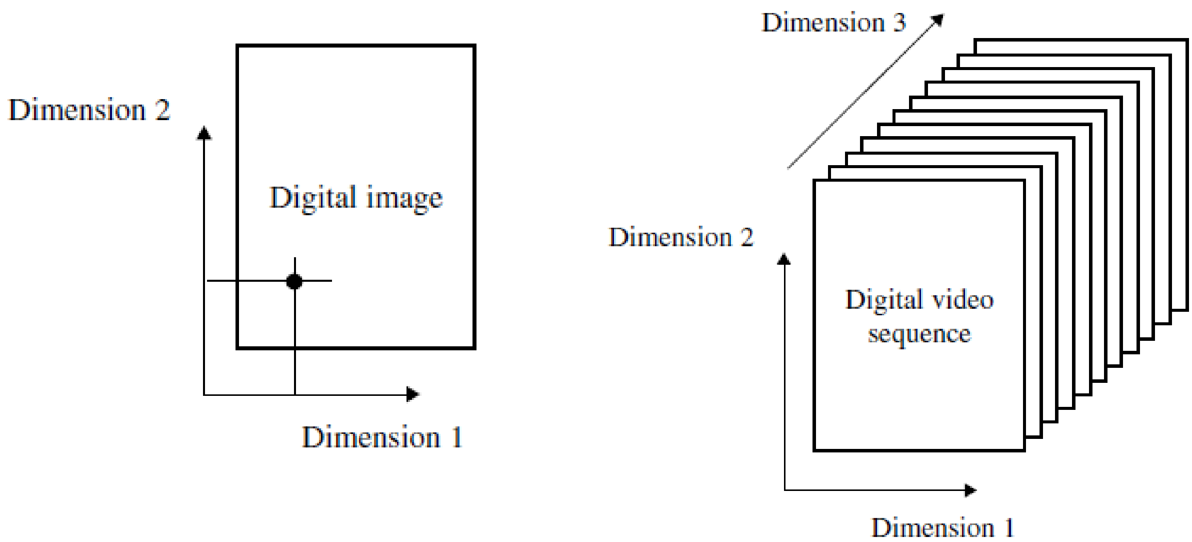
Represent Image with Compression ratio equal 27 to1

Computer Imaging Systems

Computer imaging systems are comprised of two primary components types, hardware and software. The hardware components can be divided into image acquiring sub system (computer, scanner, and camera) and display devices (monitor, printer).The software allows us to manipulate the image and perform any desired processing on the image data.

Dimension of Images

An important feature of digital images and video is that they are multidimensional signals, meaning that they are functions of more than a single variable. The signals are usually 1D functions of time. Images, however, are functions of two and perhaps three space dimensions, whereas digital video as a function includes a third (or fourth) time dimension as well. The dimension of a signal is the number of coordinates that are required to index a given point in the image. A consequence of this is that digital image processing, and especially digital video processing, is quite data-intensive, meaning that significant computational and storage resources are often required.



The dimensionality of images and video

Digital Image Representation

Digital image is composed of a finite number of element each element has a particular location and value. These elements are called pixels and their value are called the intensity or graylevel. Digital image can be represented either as:

- *One Dimensional Light intensity function.*
- *Two Dimensional Light intensity function.*

One Dimensional Light intensity function: F(x) where *x* denotes spatial position and the value of *F* at any position *(x)* is the intensity (graylevel). The image may be considered as a *1D* array whose element identifies a point in the image and the element value identifies the graylevel of that point.

Ex. : *image* ⇒ *F(x)*

Where *x=1,2, ….. , N*

N=number of points in the image

```
for i=1:N
        Disp(F(i));
end
```

Note: *i* : represent point location

F(i): represent point color

Two Dimensional Light intensity function: F(x,y) where *x,y* denote spatial coordinates and the value of F at any point *(x,y)* is the intensity (graylevel) of image at that point. Also the image *F(x,y)* may be considered as a matrix whose row and column indices identify a point in the image and the corresponding matrix element value identifies the graylevel at that point. The elements of such a digital array are called image elements, picture elements, pixels.

Ex. : *image* ⇒ *F(x,y)*

Where *x=1,2, ….. , N*

Y=1,2, …..,M

N=number of rows

M=number of column

```
for i=1:N
for j=1:M
        Disp(F(i,j));
end
end
```

Sampling and Quantization

There are numerous ways to acquire images, but the objective is how to generate digital image from sensed data, since the output of the most sensors is continuous. Converting continuous sensed data into digital form involves two processes, sampling and quantization.

So, to convert the image to digital we have to sample the function in both coordinates *(x,y)* and in amplitude.

- Digitizing the coordinate values is called sampling
- Digitizing the amplitude values is called quantization.

Conversion of the sampled analog pixel intensities to discrete valued integer number is the process of quantization.

Image Sampling

A static image is a two-dimensional spatially varying signal. The sampling period, according to Nyquist criterion, should be smaller than or at the most equal to half of the period of the finest detail present within an image. This implies that the sampling frequency along *x* axis $w_{xs} \geq 2w_x^L$ and along *y* axis $w_{ys} \geq 2w_y^L$, where w_x^L and w_y^L are the limiting factors of sampling along *x* and *y* directions. Since we have chosen sampling of Δx along *X-axis* and Δy along *Y-axis* , $\Delta x \leq \frac{\pi}{w_x^L}$ and $\Delta y \leq \frac{\pi}{w_y^L}$. The values of Δx and Δy should be chosen in such a way that the image is sampled at *Nyquist frequency.* If Δx and Δy values are smaller, the image is called oversampled, while if we choose large values of Δx and Δy the image will be undersampled. If the image is oversampled or exactly sampled, it is possible to reconstruct the bandlimited image. If the image is undersampled, then there will be spectral overlapping, which results in *aliasing effect.* We have shown images sampled at different spatial resolutions in the following figure to demonstrate that the aliasing effect increases as the sampling resolution decreases.

Figure : Images sampled at 256 x 256, 128 x 128 , 64 x 64, 32 x 32, and 16 x 16 rectangular sampling grids.

Image Quantization

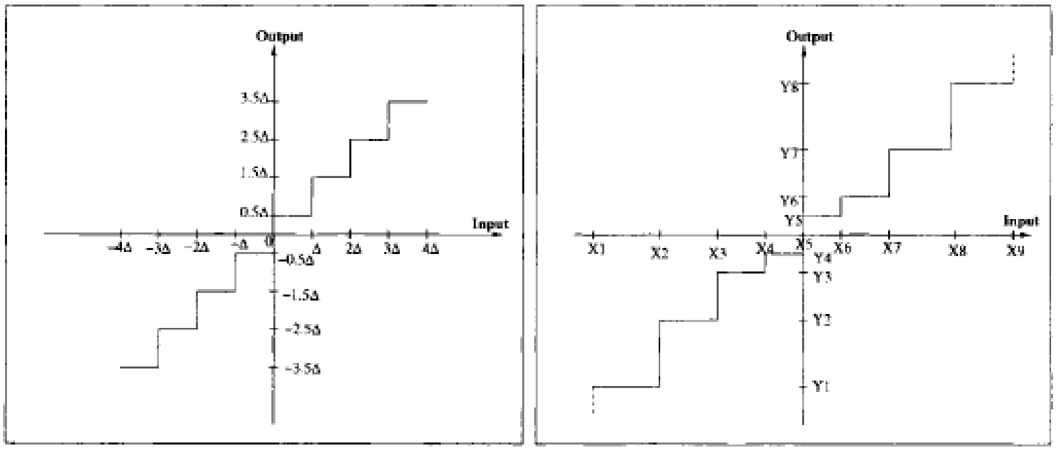
Conversion of the sampled analog pixel intensities to discrete valued integer numbers is the process of *quantization.* Quantization involves assigning a single value to each sample in such a way that the image reconstructed from the quantized sample values are of good quality and the error introduced because of quantization is small. The dynamic range of values that the samples of the image can assume is divided into a finite number of intervals, and each interval is assigned a single level.

Some of the interesting questions are as follows:

- How many quantized levels are sufficient to represent each sample?

- How do we choose the quantization levels?

As the number of quantization levels increases, obviously the quantized image will approximate the original continuous-valued image in a better way with less quantization error. When the quantization levels are chosen equally spaced at equal interval, it is known as uniform quantization. When the sample intensity values are equally likely to occur at different intervals, uniform quantization is always preferred. In many situations, however, the image samples assume values in a small range quite frequently and other values infrequently. In such a situation, it is preferable to use nonuniform quantization. The quantization in such cases should be such that they will be finely spaced in the small regions in which the sample values occur frequently, and coarsely spaced in other regions. The uniform and nonuniform quantization levels are shown in the figures (a) and (b) respectively. The process of nonuniform quantization is implemented by the process of companding, in which each sample is first processed by a nonlinear compressor, then quantized uniformly and finally again processed by an expander before reconstruction of the original image.



(a) (b)

Figure :Two-dimensional (a) uniform quantization (b) nonuniform quantization.

Monochrome and Color Image Quantization In monochrome image quantization, we assign uniform length code to each image sample. If n is the number of code-bits assigned to each sample, then the number of amplitude quantization levels $M = 2^n$. This kind of code assignment is known as *pulse code modulation* (PCM) coding. The number of levels M is so chosen that the resultant image quality is acceptable to the human observers. The eye is able to discriminate the absolute brightness of only around 15 shades of gray values, however, it is more sensitive to the difference in the brightness of adjacent gray shades. If we choose a reduced number of gray levels, the noticeable artifacts is a gray scale contouring. This contouring artifact occurs in an image where in some regions, the analog change in brightness is very slow. In the quantized image, however, this change in brightness appears as a step jump. This is shown in the following figure, where the effect of reduction of the number of quantized levels is prominently observed, specially in those regions of the image where the brightness changes very slowly.

A color image, represented by red, green, and blue components, is quantized in individual color bands. When each color component is linearly quantized over a maximum range into 2^n levels, then each color sampled pixel is quantized in ***3n*** bits, because it requires *n* bits for each color component.

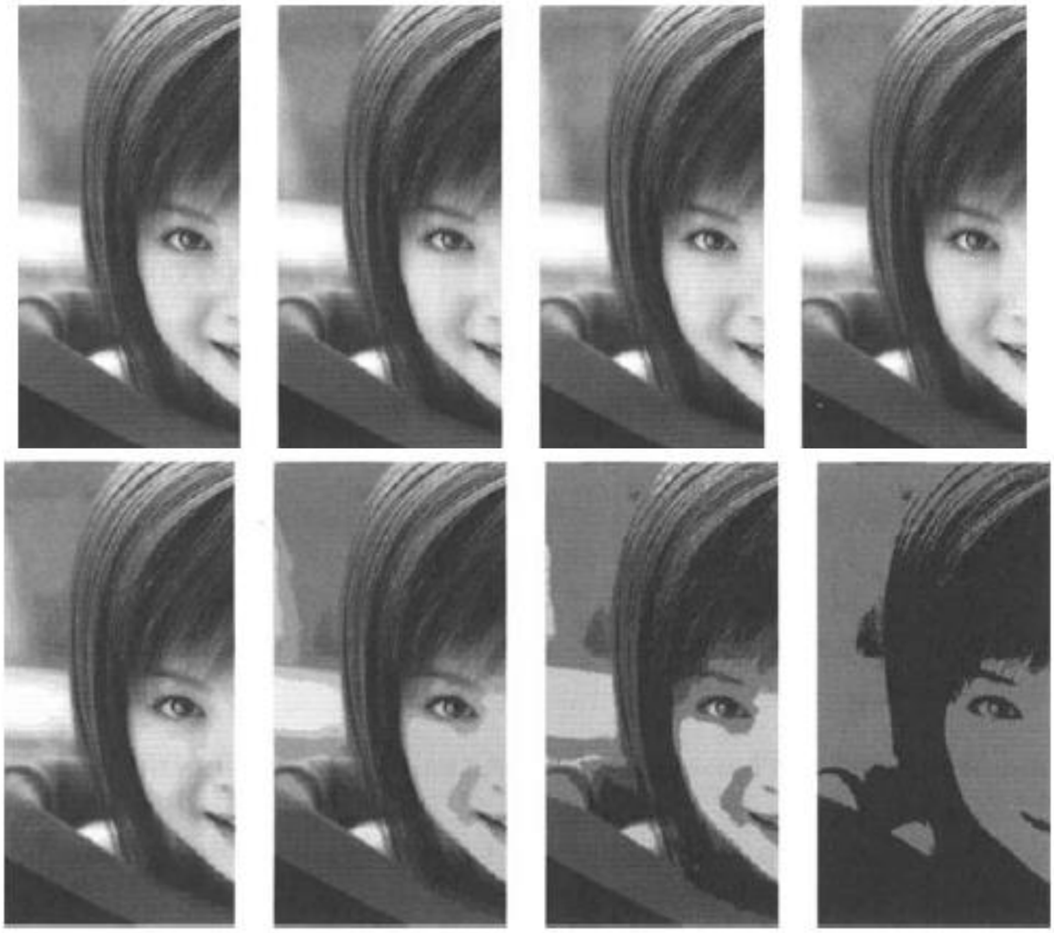


Figure: Image quantization: results of finer to coarser quantization.