A Comprehensive Study of Digital Image Processing for Finding Image Quality Dependencies

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***Abstract*- Every** digital image processing system can be represented by a block diagram containing three main elements. Image processing started with the input of an image in the processing system. The integrated software within the chip handles the task. Again it can be further processed based on the need. But the application of the processing method or algorithm depends on how the image is inputted, and stored. The quality of the processed image also depends on many criterions. In this article digital processed image quality comparison, hardware comparison and human perception and visual limitations are analyzed to find out common quality dependencies of processed image. The objective of this article is to educate newcomer to basic and fundamental technique of different types of image processing and to find out common image quality dependencies. All fundamental algorithms of image processing will be discussed and quality of processed image output comparison will be shown to find out dependencies.

***Index Terms*-** Canny Edge Detection, CCD architecture, Digital Image Processing, Image algebra, Image Quality standard

I. Introduction

Image processing is a form of signal processing for which the input is an image, such as photographs; the output of image processing can be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. Image processing is done by using Software. For example: color operation, image enhancement/ analysis and another. This is done through the development and implementation of processing algorithms on the image. Processing image using a digital computer provides the greatest flexibility and power for general image processing application, since the programming of a computer can be changed easily which allows operation to be modified quickly. From fourth -generation digital computers began to offer the speed and storage capabilities required for practical implementation of Image processing algorithms. Since then, this area has experienced vigorous growth and has been subjected of study and research in such fields as engineering, computer science, statistics, information science, physics, chemistry and medicine. The result of these efforts have established the value of image processing technique in of problem with application in diverse fields, including automated factory Controlled, astronomy, meteorology, agriculture, medicine, art and military application. With the increasing availability of reasonably inexpensive hardware and some very importance application on the horizon, image techno logy is expected to continue its growth and to play an important role in the future.

II. Digital Images

A digital image is a discrete two-dimensional function. *f (x. y)*, which has been quantized over its domain and range. Without loss of generality, it will be assumed that the image is rectangular, consisting of Y rows and X columns. The resolution of such an image is written as X×Y. By convention, f (0, 0) is taken to be the top left corner of the image and *f* (X-1, Y-1) the bottom right corner. This is summarized in Figure 2.1.

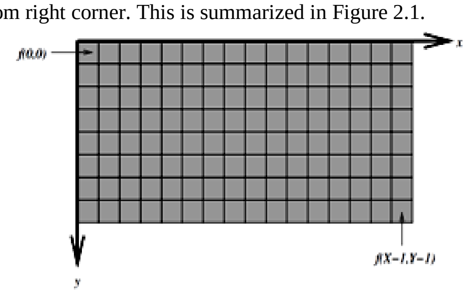


Figure 2.1: A rectangular digital image of resolution 16 x 8.

2.1 Image statistics

2.1.1 The histogram

A histogram plots the relative frequency of each pixel value that occurs in a grayscale image. The histogram provides a convenient summary of the intensities in an image, but is unable to convey any information regarding spatial relationships between pixels. In this example, the image does not contain many very low or very high intensity pixels. It is possible that peaks in the histogram correspond to objects in the image, but it is difficult to be certain without visually examining the image.

2.1.2 The mean

The image mean is the average pixel value of an image. For a grayscale image this is equal to the average brightness or intensity. Let the image f (x, y) be referred to using the shorthand

f. The mean of this image, E[f], may be calculated using Equation 2.1.

$$E[\ f\ ] = \frac{1}{YX}\sum_{y=0}^{Y-1}\sum_{x=0}^{X-1} f(x, y) \quad 2.1$$

2.1.3 The variance

The image variance, Var[f], gives an estimate of the spread of pixel values around the image mean. It can be calculated using either Equation 2.2 or Equation 2.3. The latter has the advantage of requiring only one pass through the image. The stands d deviation is simply $\sqrt{Var[f]}$

$$Var[f] = E[\ f - E[f]\ ]^2 \quad (2.2)$$

$$Var[f] = E[f^2] - E[f]^2 \quad (2.3)$$

2.1.4 The entropy

The image histogram may be considered a probability distribution over pixel values. For the case of a Z level grayscale image, the histogram entry for intensity z may be written as Pr(z). The entropy of an image, f, is given by Equation 2.4. The units of entropy are bits when using logarithms to base 2.

$$H(f) = \sum_{z=0}^{Z-1} \Pr(z) \log_2 \Pr(z) \qquad bits \quad (2.4)$$

The entropy has a maximum value of $\log_2$ when all intensities occur will equal frequency, corresponding to a uniform histogram. It has a minimum value of 0 when all pixels have the same intensity. The entropy is one measure of the information content of an image. Because it is calculated from the histogram, it is unable to take spatial factors into consideration.

2.2 Image algebra

2.2.1 Image-scalar operations

Various useful arithmetical operations may be defined for images. Let ⊗ represent the binary operator for addition, subtraction, multiplication, or division. Equation 2.5 shows how to combine a scalar c, and an image g, to produce a new image, f. This is a pixel-wise operation; each pixel in g is operated on using ⊗ with c, and the result put in f.

$$f = g \otimes c \equiv \forall(x, y)\ \ f(x, y) = g(x, y) \otimes c \quad (2.5)$$

This idea could be used to enhance an image which is too dark. Consider the image in Figure 2.4a which uses 8 bits per pixel (256 levels), but only contains pixels with intensities from 64 to 191. One may consider enhancing it to use the full intensity range. This can be achieved using Equation 2.6, where [.] denotes integer truncation and floating point precision is used for all pixels during the calculation. The result is given in Figure 2.6b.

$$f = \left[\frac{g - 64}{128} \times 255\right] \quad (2.6)$$

Figure 2.2: (a) low contrast image (b) after enhancement

2.2.2 Image-image operations

The image-scalar operation may be extended to the combination of two images, g_1 and g_2, having the same resolution. Instead of combining a scalar with each pixel, two pixels with the same coordinate in different images are used instead. Equation 2.7 describes this process.

$$f = g1 \otimes g2 \equiv \forall(x, y)$$

$$f(x, y) = g1(x, y) \otimes g2(x, y) \quad (2.7)$$

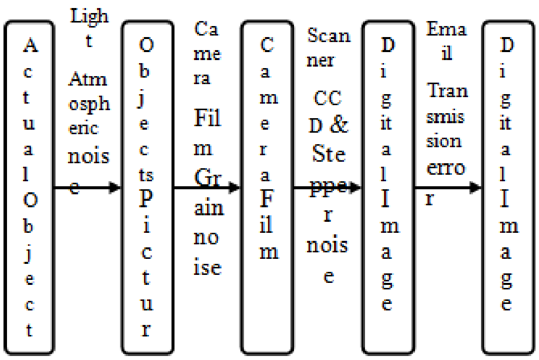
To generate a blended version of two grayscale images of identical resolution equation 1.8 can be used, where α determines the mixing proportion. Alpha blending is a simple form of morphing and is often used to dissolve between scenes in film and television. A visual example for α=0.5 is given in Figure 2.4.

$$f = [\ \alpha \times g_1 + (1- \alpha) \times g_2\ ] \quad (2.8)$$

Figure 2.3: Alpha-blending example: (a) first image; (b) second image; (c) blended image using α=0.5

2.3 Image acquisition

Image acquisition is the process of obtaining a digitized image from a real world source. Each step in the acquisition process may introduce random changes into the values of pixels in the image. These changes are called *noise*. Suppose a photo is needed to send over the Internet to somebody. This may be achieved by taking a photograph with a conventional camera, having the film made into a print, scanning the print into a computer and finally emailing it to destination



2.4: Noises in each step of image acquisition process

The air between the photographer and the object may contain dust particles which interfere with the light reaching the camera lens. The silver-halide crystals on the film vary in size and are discontinuous, resulting in film grain noise in the printing process. Most scanners use a CCD array to scan a row of the print, which may introduce photo-electronic noise. The scanner's CCD array is controlled by a fine stepper motor. This motor has some degree of vibration and error in its movement, which may cause pixels to be misaligned. The scanner also quantizes the CCD signal, introducing quantization noise. Transmitting the image over the Internet is nearly always a bit preserving operation and error checking by network protocols. However, an image transmitted to Earth from a remote space probe is almost guaranteed to contain errors.

III. The Image Processing Algorithms

3.1 Two dimensional (2-D)

Gaussian Smoothing Noise caused by sensor electronics, and introduced in signal transmission can reduce the visual quality of an image. So, it is desirable to remove it before image analysis. The 2-D Gaussian smoothing is a convolution operation, and a low-level image processing algorithm, that is used to remove detail and suppress noise. Smoothing is among the key techniques in image processing which can be implemented in both spatial domain and frequency domain. Compared with the frequency domain techniques, the spatial domain techniques are faster and easier to implement. It uses a moving kernel that represents the shape of a Gaussian hump. For a pixel, the intensity is replaced with the sum of the product between the intensity values within a neighboring area centered at the pixel and the coefficients of the kernel. Thus, any fine structure that is smaller than the filter's kernel size gets removed. For a Gaussian function with standard deviationσ, a 1-D Gaussian filter can be written as:

$$G_x = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{x^2}{2\sigma^2}}$$

A 2-D, isotropic Gaussian filter can be expressed as a product of two 1-D Gaussians:

$$\begin{aligned} G_{x,y} &= \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \\ &= G_x G_y \end{aligned}$$

The idea of Gaussian smoothing is to use this 2-D distribution as a 'point-spread' function, and this is achieved by convolution. Since the image is stored as a collection of discrete pixels we need to produce a discrete approximation to the Gaussian function before we can perform the convolution. Theoretically, the Gaussian distribution is non-zero everywhere, hence requiring an infinitely large convolution kernel, but practically it is effectively zero at more than about three standard deviations from the mean, and the kernel can truncated at this point. Figure 3.1 shows a suitable integer-valued convolution kernel that approximates a Gaussian with a (σ) of 1.0.

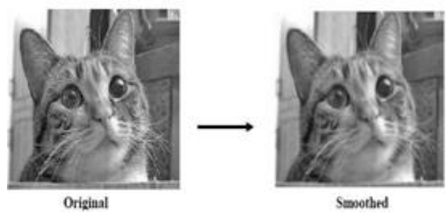


Figure 3.1: Input to and output of Gaussian Smoothing

The effect of Gaussian smoothing is to blur an image, in a similar fashion to the mean filter. The degree of smoothing is determined by the standard deviation of the Gaussian. The Gaussian outputs a 'weighted average' of each pixel's neighborhood, with the average weighted more towards the value of the central pixels. This is in contrast to the mean filter's uniformly weighted average. Because of this, a Gaussian provides gentler smoothing and preserves edges better than a similarly sized mean filter.

3.2 Canny Edge Detection

Edge detection is one of the most commonly used operations in image analysis providing strong visual clues that can help the recognition process. Edges are local variations in a image function defined by a discontinuity in gray level values and have strong intensity contrasts. Canny Edge Detection is an optimal edge-detector algorithm that maximizes the probability of detecting true edges while minimizing the probability of false edges. It is an intermediate-level image processing operation implemented in three stages, namely:

- gradient estimation
- non-maximal suppression
- edge-linking by hysteresis

The algorithm first smoothes the image to eliminate noise through convolution with Gaussian kernel. It then finds the image gradient to highlight regions with high spatial derivatives. To achieve this, a separable Gaussian kernel (*Gx,Gy*) and its derivative (*G'x, G'y*) need to be generated. The reason behind using a Gaussian kernel is because a Gaussian function is completely described by its first and second order statistics.

ISSN 2250-3153

These kernels can be of variable kernel width (*w*) and variance (σ).

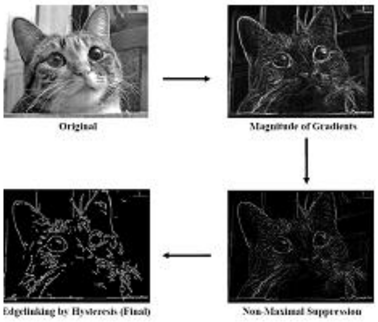


Figure 3.2: Input to and outputs from each of three stages of Canny Edge Detection

The calculation of gradients, (g_x, g_y) in X and Y directions respectively, for an image (*I*) involves smoothing of the image along one axis followed by convolving it with derivative of other axis. This process can be mathematically denoted as:

$$g_x(x,y) = I * G_y(x,y) * G'_x(x,y) \quad \text{and} \quad g_y(x,y) = I * G_x(x,y) * G'_y(x,y)$$

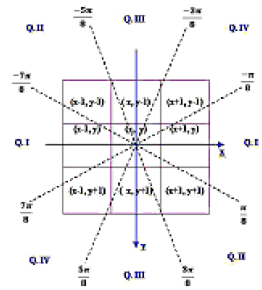
The gradient magnitude can be determined in terms of Euclidean distance measure. To reduce computational complexity, Manhattan distance measure is used instead, and thus gradient magnitude gets simplified into

$$| g_x(x,y) | = | g_x(x,y) | + | g_y(x,y) |$$

Although the edges in gradient magnitudes image are usually well indicated, the spatial position for a thick or blurry edge cannot be determined correctly. A thick edge is made sharp through the elimination of unnecessary edge-pixels wherein the value of an edge-pixel is decided on the basis of its gradient direction. The method is called non-maximal suppression of edges. The gradient direction, $\theta(x, y)$, is the direction of the maximum slope formed by the vector addition of the image gradients in x and y directions given by

$$\theta(x,y) = \tan^{-1}\left[\frac{g_y(x,y)}{g_y(x,y)}\right]$$

The non-maximal suppression algorithm finds the local maxima in the direction of the gradient, and suppresses any pixel that is not at the maximum (non-maximal). This is done by labeling all possible edges in the image and disregarding all of the non-edges. To implement this, the pixels of the gradient magnitude image are grouped based on the four quadrants that their corresponding angles of the gradient direction fall in (Fig 3.3).



Theta Values	Pixel Positions	Quadrant
$\theta \le \frac{\pi}{8}$ or $\theta \le \frac{7\pi}{8}$	(x-1, y) & (x+1, y)	1
$\frac{\pi}{8} < \theta \le \frac{3\pi}{8}$	(x-1, y-1) & (x+1, y+1)	2
$\frac{3\pi}{8} < \theta \le \frac{5\pi}{8}$	(x, y-1) & (x, y+1)	3
$\frac{5\pi}{8} < \theta \le \frac{7\pi}{8}$	(x-1, y+1) & (x+1, y-1)	4

Figure 3.3: Angles and quadrants

Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two threshold values and the result contains all the one-pixels coming from the high threshold and those one-pixels from the low threshold that are connected to a high threshold pixel through eight-connected neighborhoods. This threshold technique improves edge localization. The high and low threshold values can be found from the statistics of the image. For the high threshold, a histogram of image magnitude gradient is created. From the histogram, a certain percent of the highest magnitude pixels are chosen to be definite edges. The percentage that yields the most reasonable results is used. Most edge detectors work on the grayscale representation of the image. This reduces the amount of data to work with, from three channels to one, but at the cost of losing some information about the scene. By including the color component of the image, the edge detector should be able to detect edges in regions with high color variation but low intensity variation. To Canny edge detector can be extended to perform color edge detection, and differs little from the traditional grayscale version. The algorithm reads in a color image and divides it into its three separate color channels. Then, each color channel is run through the Canny edge detector separately to find a resulting colored edge map. Finally, the resulting edge maps from each of the three color channels are combined into one complete edge map. Color edge detection seems like it should be able to outperform grayscale edge detectors since it has more information about the image.

Figure 3.4: Comparing results of grayscale and color Canny edge detection.

LEFT: Input image “Lena” of size 1024×1024 pixels.
CENTER: Output of Grayscale Canny edge detector with σ = 0.8, Gaussian kernel size = 5×5.
RIGHT: Output of Color Canny edge detector with σ = 0.8, Gaussian kernel size = 5×5.

From Fig. 3.4, we can see that in the case of the Canny color edge detector, it finds slightly more number of edges than the grayscale version. Finding an optimal way to combine the three color challenges may improve this method. But, from a practical viewpoint, this difference may be significant to real world applications that depend more on efficiency than marginal improvement of results

3.3 Digital Filters

The digital filter can be categorized as a low pass or high pass filter depending on which part of the frequency spectrum it affects. The effect on a composite electrical analog signal containing all frequency components. The output signal o f the high pass filter will contain the high frequency components. The output signal of the low pass filter will contain the DC bias and low frequency components. The specific cutoff frequency cab be varied the selection of the value used in the filter, but that is beyond the scope of this course. The low frequency components in an image are characterized by a slow change in the contrast or values of adjacent pixel in relation to high frequency components, due to the rapid change in contrast encountered at the edge of an object.

3.3.1 Low Pass Filter

The low pass filter will not affect low frequency components in the image data and will attenuate the high frequency components as illustrated in figure 3.5. Random speckles in an image can be considered as noise and are high frequency components since the pixel values of adjacent pixels change very rapidly. The effect of the speckles can be reduced by using a simple averaging filter. The coefficient matrix for an averaging filter for a 3x3 local area convolution would contain nine elements as shown below.

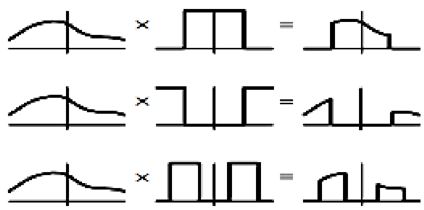


Figure 3.5: Top: Low pass Mid: High pass Bottom: Band Pass.

3.3.2 High Pass Filter

The high pass digital filter has the inverse characteristic of low pass filter. The filter will not change the high frequency component of a signal and will attenuate the low frequency component as well as eliminate any bias in the signal. The effect of background light would result in a DC bias in the vision system data since the minimum value of all pixel would be above some given some given value.

IV. Imaging Hardware

4.1 CCD

CCDs consist of thousands (or millions) of light sensitive cells or pixels that are capable of producing an electrical charge proportional to the amount of light they receive. Typically, the pixels are arranged in either a single line (linear array CCDs) or in a two-dimensional grid (area array CCDs). Each cell is essentially a MOS capacitor, of which there are two types: *surface channel* and *buried channel*. The two differ only slightly in their fabrication, however; buried channel capacitors offer major advantages, and because of this, nearly all CCDs manufactured today use this preferred structure.

4.2 CMOS

CMOS image sensors typically come in two forms: *passive pixel* and *active pixel*. Passive pixel devices have charge amplifiers at the bottom of each column of pixels, with each pixel having just a single transistor (in addition to the photodiode and capacitor). This transistor is used as a charge gate and switches the contents of each pixel's capacitor to the charge amplifier. Active pixel arrays implement an amplifier in every pixel. Both passive and active pixel arrays use the same technique for reading the image out of the array. Each of the row selectors are sequentially clocked. This in turn causes the switching transistor or charge amplifier for that row of pixels to activate and thus transfer each pixel's charge to the column outputs.

4.3 Color Filter

Color filter array over each individual photosite are used to break up the sensor into a variety of red, blue and green pixels. It is possible to get enough information in the general vicinity of each sensor to make very accurate guesses about the true color at that location. This process of looking at the other pixels in the neighborhood of a sensor and making an educated guess is called **interpolation**. The most common pattern of filters is the **Bayer filter pattern**. This pattern alternates a row of red and green filters with a row of blue and green filters. The pixels are not evenly divided -- there are as many green pixels as there are blue and red combined. This is because the human eye is not equally sensitive to all three colors. It's necessary to include more information from the green pixels in order to create an image that the eye will perceive as a "true color." The advantages of this method are that only one sensor is required, and all the color information (red, green and blue) is recorded at the same moment. That means the camera can be smaller, cheaper, and useful in a wider variety of situations. The raw output from a sensor with a Bayer filter is a mosaic of red, green and blue pixels of different intensity. Digital cameras use specialized **demosicing algorithms** to convert this mosaic into an equally sized mosaic of true colors. The key is that each colored pixel can be used more than once. The true color of a single pixel can be determined by averaging the values from the closest surrounding pixels. Some single-sensor cameras use alternatives to the Bayer filter pattern. X3 technology, for example, embeds red, green and blue photo detectors in silicon

V. Digital Image Processing

Digital image processing is a form of signal processing for which the input is an image, such as photographs; the output of image processing can be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. For processing an image first we need to input or generate an image first then using appropriate algorithm is needed based on our need to process it. Then we will get the desired output.

5.1 Image Generation

Mostly Light waves are used for image generation which travels through a vacuum. A light wave consists of energy in the form of electric and magnetic fields. The fields vibrate at right angles to the direction of movement of the wave, and at right angles to each other. Because light has both electric and magnetic fields, it is referred to as electromagnetic radiation Light waves come in many sizes. The size of a wave is measured as its wavelength**,** which is the distance between any two corresponding points on successive waves, usually peak-to-peak or trough-to-trough. The wavelengths of the light we can see range from 400 to 700 billionths of a meter. But the full range of wavelengths included in the definition of electromagnetic radiation extends from one billionth of a meter, as in gamma rays, to centimeters and meters, as in radio waves. Light is one small part of the Electromagnetic (EM) energy spectrum. There is some other wave energy which is also used for image generation. Such as Ultrasonic energy Electric energy (used in electron microscope) There are also senthetic images that can be generated by using computer software. Such as Fractals (iterative reproduction of a basic pattern by some mathematics rules) and images used in 3D modeling, medical training, special effects etc.

In this article we will study image processing which are generated using visual light spectrum for simplicity. These images are generated by capturing reflected light from the object using CCD. Any type of input device which uses light for taking image input uses CCD chip for capture.

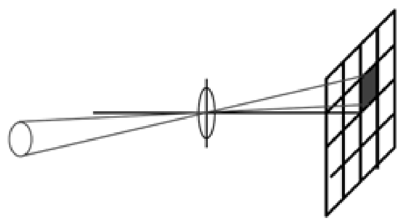


Figure 5.1: Reflected light focused on CCD plane

5.2 Capturing Color

There are three color models that are followed for digital image processing (a) RGB color model to represent image on monitor or LCD screen (b) CMY; CMYK color model for printing with color printer (c) HSI model Also used for represent image on monitor and separate gray-scale and color information.Unfortunately, each photo site is colorblind. It only keeps track of the total intensity of the light that strikes its surface. In order to get a full color image, most sensors use filtering to look at the light in its three primary colors. Once the camera records all three colors, it combines them to create the full spectrum. There are several ways of recording the three colors in a digital camera. The highest quality cameras use three separate sensors, each with a different filter.

5.3 Image Format and post processing

On chip integrated circuits and firmware processes grabbed image and saves it in different formats based on standard compression algorithm. These Image files are composed of pixels, vector (geometric) data, or a combination of the two. Whatever the format, the files are rasterized to pixels when displayed on most graphic displays. Image formats can be grouped into three. Some popular image formats are

- Raster formats such as JPEG, JPEG 2000, TIFF, RAW, PNG, GIF, BMP, PPM, PGM, PBM, PNM, WEBP etc.
- Vector Formats such as CGM, Gerber Format (RS-274X), SVG etc. and
- Stereo formats such as PNS, JPS etc.

These stored images can be processed again based on the needs using software which can be categorized as:

- Low-level: both input and output are images (Noise reduction, contrast enhancement, image sharpening etc.)
- Mid-level: input -image, output –extracted attributes (Segmentation, classification, color correction etc.)
- High level: "making sense" of the images (Vision-related tasks, Image recognition etc.)

5.4 Representing Digital Images

Frame buffer holds a 2D array of numbers representing intensities. The display creates a continuous light image from these discrete digital values. We say that the discrete image is reconstructed to form a continuous image. Although it is often convenient to think of each 2D pixel as a little square that abuts its neighbors to fill the image plane, this view of reconstruction is not very general. Instead it is better to think of each pixel as a point sample.

VI. Processed Image Quality

- Image quality is the integrated set of perceptions of the overall degree of excellence of an image (Engeldrum, 2000).
- Image quality is understood as the subjective impression of how well image content is rendered or reproduced (Yendrikhovskij, 2002).
- The quality of an image is defined to be an impression of its merit or excellence, as perceived by an observer neither associated with the act of photography, nor closely involved with the subject matter depicted (Keelan, 2002).

According to the International Imaging Industry Association [2007], image quality is the perceptually weighted combination of significant attributes (contrast, graininess, etc.) of an image when considered in its marketplace or application. Thus the quality of an image is its degree of adequacy to its function/goal within a specific application field

- This definition does not see image quality per se, but considers that a lack of coincidence may exist between the acquired and the desired scenes.
- This definition does not assume that the image receiver is a human but it could be a computational system moreover it makes more evident the relationship between the process of image generation and image quality assessment.
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6.1 Image Quality Standards

Raw data produced by a CCD sensor and generates the digital images that will then be viewed by the user or undergo further processing before being saved to nonvolatile memory. A series of specialized algorithms that adjusts image data in real-time and is often implemented as an integrated component of a system-on-chip image processor. With an image pipeline implemented in hardware, front-end image processing can be completed without placing any processing burden on the main application processor. This allows the cycles to encode and perform advanced processing functionalities such as video analytics including object recognition and object tracking. On the other hand, quality has no standard. This article proposes some common quality dependencies on which image quality differs. In order to maximize quality, image processing pipeline needs to be readily flexible and configurable to provide the highest quality for each individual picture

6.2 Quality Assessment

Assessment is usually done by one or more of the following direct methods: Psychophysical experiments involving human observers (subjective) and computing suitable metrics directly from the digital image (objective). Image quality can be sometimes indirectly assessed by quantifying the performance of an image-based task done by the domain expert and/or by a computational system (objective). And by assessing the performance of the imaging/rendering devices on suitable set of target images using ad-hoc designed software tools one or more direct methods (objective/subjective).

6.3 Image Quality dependents

6.3.1 Human Eye Perception

Light travels in straight lines, so visual information can be used to determine both the direction and distance of an object. No other human stimulus provides as much detail as the human eye. Vision**,** the perception of light, is carried out through the eye, which contains receptors that detect photons of light. The eye is organized similar to a camera. The receptors are located in the back of the eye and are categorized as either rods, which are receptors for black and white vision, or cones, which are receptors for color. There are three different kinds of cones, cells that absorb either red, green, or blue wavelengths of light to give humans color vision. The field of receptors that line the back of the eye is called the retina. The retina contains approximately three million cones and one billion rods.

Having two eyes looking at the same object or scene causes each eye to see slightly different images because they are viewed from slightly different angles. This slight displacement of the images, called parallax, permits very sensitive depth perception. By comparing the differences between the images provided by each eye with the physical distance to specific objects, humans learn to interpret distance through stereoscopic vision.

6.3.1.1 Brightness Adaptation & Discrimination

Light intensity levels to which we can adapt is 10^{10}

- It is not a simultaneous operation.
- Brightness adaptation level is given sensitivity level for a set of conditions.
- Light intensity changes can be detected too.
- Perceived brightness does not merely depends on intensity; human visual system overshoots / undershoots around the boundary of regions of different intensities

Simultaneous contras

Figure 6.1: Mach Band

6.3.1.2 Illumination

Sometimes some image creates visual illumination in our brain creates a wrong perception. Such as

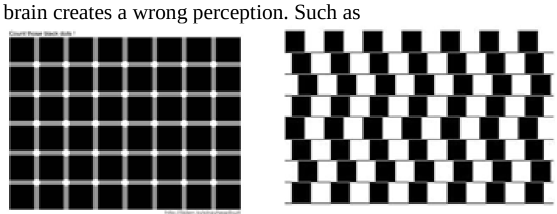

Figure 6.2: Optical Illution

6.3.2 Jaggies

Sampling process is not perfect. Thus sometimes lines drawn apperas as stair like pattern called jaggies. For senthetic image made with formula produces optical illution because of jaggies

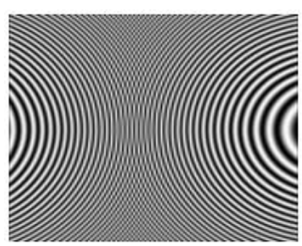

Figure 6.3 Jaggies caused optical illution

6.3.3 Processing Hardware

6.3.3.1 CCD architecture

New architecture of pixel interleaved array (PIA) CCD is designed with the concept to maximize the space efficiency in a pixel pattern layout by rotating the pixel 45° . PIACCD has the advantages as follows:

1) A progressive scan CCD is realized using standard double-layer poly-Si technology.

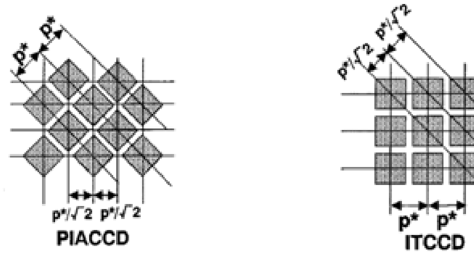

Figure 6.4: Pixel Array in ITCCD and PIACCD

2) The active area in a pixel is enlarged 1.3 times in comparison with the same pixel size ITCCD.
3) The 1.4 times enlarged equilateral shaped aperture opened above each photodiode has an advantage to heighten the sensitivity.
4) The resolution is fundamentally 1.4 times as high as that of ITCCD in horizontal and vertical directions. This property fits in both characteristics of human eye and natural scenery.

(a) (b)

Figure 6.5: (a) PIACCD image. (b) ITCCD image.

The 2.4M-pixel sensor with 4.52 m pixel size has provided the sensitivity 1.3 times higher than that of conventional same pixel size ITCCD, and the dynamic range of 71 dB. 1100 TV-line pair could be read off in the reproduced resolution chart image. It corresponds to the 1.4 times high resolution.

VII. CONCLUSION

Thus we can conclude that image quality is a function of (a) Object environment (such as: type of scene, scene geometry, Lighting conditions, Specific content etc.), (b) Processing Hardware architecture (such as: Imaging device, Image Processing and transmission system, Rendering device etc.) and (c) Human perception (such as: Observer's adaptation state and viewing conditions, Observers' previous experiences, preferences and expectations etc). The viewing conditions have a significant influence on the appearance of an image or because they can amplify or diminish the visibility of artifacts.

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