NIILM University

Digital Imaging

CONTENT

Chapter 1

Digital Imaging

Digital imaging or digital image acquisition is the creation of digital images, typically from a physical scene. The term is often assumed to imply or include the processing, compression, storage, printing, and display of such images. The most usual method is by digital photography with a digital camera but other methods are also employed.

History

Digital imaging was developed in the 1960s and 1970s, largely to avoid the operational weaknesses of film cameras, for scientific and military missions including the KH-11 program. As digital technology became cheaper in later decades, it replaced the old film methods for many purposes.

The first digital image was produced in 1920, by the Bartlane cable picture transmission system. British inventors, Harry G. Bartholomew and Maynard D. McFarlane, developed this method. The process consisted of “a series of negatives on zinc places that were exposed for varying lengths of time, thus producing varying densities, The Bartlane cable picture transmission system generated at both its transmitter and its receiver end a punched data card or tape that was recreated as an image.

In 1957, Russell A. Kirsch produced a device that generated digital data that could be stored in a computer; this used a drum scanner and photomultiplier tube.

In the early 1960s, while developing compact, lightweight, portable equipment for the onboard nondestructive testing of naval aircraft, Frederick G. Weighart and James F. McNulty at Automation Industries, Inc., then, in El Segundo, California co-invented the first apparatus to generate a digital image in real-time, which image was a fluoroscopic digital radiograph. Square wave signals were detected by the pixels of a cathode ray tube to create the image.

These different scanning ideas were the basis of the first designs of digital camera. Early cameras took a long time to capture an image and were poorly suited for consumer purposes. It wasn’t until the development of the CCD (charge-coupled device) that the digital camera really took off.

The CCD became part of the imaging systems used in telescopes, the first black and white digital cameras and camcorders in the 1980s. Color was eventually added to the CCD and is a usual feature of cameras today.

The changing environment: Great strides have been made in the field of digital imaging. Negatives and exposure are foreign concepts to many, and the first digital image in 1920 led eventually to cheaper equipment, increasingly powerful yet simple software, and the growth of the Internet.

The constant advancement and production of physical equipment and hardware related to digital imaging has effected the environment surrounding the field. From cameras and webcams to printers and scanners, the hardware is becoming sleeker, thinner, faster, and cheaper. As the cost of equipment decreases, the market for new enthusiasts widens, allowing more consumers to experience the thrill of creating their own images.

Everyday personal laptops, family desktops, and company computers are able to handle photographic software. Our computers are more powerful machines with increasing capacities for running programs of any kind—especially digital imaging software. And that software is quickly becoming both smarter and simpler. Although functions on today's programs reach the level of precise editing and even rendering 3-D images, user interfaces are designed to be friendly to advanced users as well as first-time fans.

The Internet allows editing, viewing, and sharing digital photos and graphics A quick browse around the web can easily turn up graphic artwork from budding artists, news photos from around the world, corporate images of new products and services, and much more. The Internet has clearly proven itself a catalyst in fostering the growth of digital imaging.

Online photo sharing of images changes the way we understand photography and photographers. Online sites such as Flikr, Shutterfly, and Instagram give billions the capability to share their photography, whether they are amateurs or professionals. Photography has gone from being a luxury medium of communication and sharing to more of a fleeting moment in time. Subjects have also changed. Pictures used to be primarily taken of people and family. Now, we take them of anything. We can document our day and share it with everyone with the touch of our fingers.

Field advancements: Digital imaging has demonstrated its worth in a variety of fields from education to medicine. As digital projectors, screens, and graphics find their way to the classroom, teachers and students alike are benefitting from the increased convenience and communication they provide, although their theft can be a common problem in schools. In addition acquiring a basic digital imaging education is becoming increasingly important for young professionals. Reed, a design production expert from Western Washington University, stressed the importance of using “digital concepts to familiarize students with the exciting and rewarding technologies found in one of the major industries of the 21st century”.

The field of medical imaging, a branch of digital imaging that seeks to assist in the diagnosis and treatment of diseases, is growing at a rapid rate. A recent study by the American Academy of Pediatrics suggests that proper imaging of children who may have appendicitis may reduce the amount of appendectomies needed. Further advancements include amazingly detailed and accurate imaging of the brain, lungs, tendons, and other parts of the body—images that can be used by health professionals to better serve patients.

There is a program called Digital Imaging in Communications and Medicine (DICOM) that is changing the medical world as we know it. DICOM is not only a system for taking high quality images of the aforementioned internal organs, but also is helpful in processing those images. It is a universal system that incorporates image processing, sharing, and analyzing for the convenience of patient comfort and understanding. This service is all encompassing and is beginning a necessity.

Theoretical application: Although theories are quickly becoming realities in today’s technological society, the range of possibilities for digital imaging is wide open. One major application that is still in the works is that of child safety and protection. How can we use digital imaging to better protect our kids? Kodak’s program, Kids Identification Digital Software (KIDS) may answer that question. The beginnings include a digital imaging kit to be used to compile student identification photos, which would be useful during medical emergencies and crimes. More powerful and advanced versions of applications such as these are still developing, with increased features constantly being tested and added.

But parents and schools aren’t the only ones who see benefits in databases such as these. Criminal investigation offices, such as police precincts, state crime labs, and even federal bureaus have realized the importance of digital imaging in analyzing fingerprints and evidence, making arrests, and maintaining safe communities. As the field of digital imaging evolves, so does our ability to protect the public.

Digital imaging can be closely related to the social presence theory especially when referring to the social media aspect of images captured by our phones. There are many different definitions of the social presence theory but two that clearly define what it is would be "the degree to which people are perceived as real" (Gunawardena, 1995), and "the ability to project themselves socially and emotionally as real people" (Garrison, 2000). Digital imaging allows one to manifest their social life through images in order to give the sense of their presence to the virtual world. The presence of those images acts as an extension of oneself to others, giving a digital representation of what it is they are doing and who they are with. Digital imaging in the sense of cameras on phones helps facilitate this effect of presence with friends on social media. Alexander (2012) states, "presence and representation is deeply engraved into our reflections on images...this is, of course, an altered presence...nobody confuses an image with the representation reality. But we allow ourselves to be taken in by that representation, and only that 'representation' is able to show the liveliness of the absentee in a believable way." Therefore, digital imaging allows ourselves to be represented in a way so as to reflect our social presence.

Methods: A digital photograph may be created directly from a physical scene by a camera or similar device. Alternatively, a digital image may be obtained from another image in an analog medium, such as photographs, photographic film, or printed paper, by an image scanner or similar device. Many technical images—such as those acquired with tomographic equipment, side-scan sonar, or radio telescopes—are actually obtained by complex processing of non-image data. Weather radar maps as seen on television news are a commonplace example. The digitalization of analog real-world data is known as digitizing, and involves sampling (discretization) and quantization.

Finally, a digital image can also be computed from a geometric model or mathematical formula. In this case the name image synthesis is more appropriate, and it is more often known as rendering.

Digital image authentication is an issue for the providers and producers of digital images such as health care organizations, law enforcement agencies and insurance companies. There are methods emerging in forensic photography to analyze a digital image and determine if it has been altered.

Previously digital imaging depended on chemical and mechanical processes, now all these processes have converted to electronic. A few things need to take place for digital imaging to occur, the light energy converts to electrical energy- think of a grid with millions of little solar cells. Each condition generates a specific electrical charge. Charges for each of these "solar cells" are transported and communicated to the firmware to be interpreted. The firmware is what understands and translates the color and other light qualities. Pixels are what is noticed next, with varying intensities they create and cause different colors, creating a picture or image. Finally the firmware records the information for future and further reproduction.

Advantages: There are several benefits of digital imaging. First, the process enables easy access of photographs and word documents. Google is at the forefront of this 'revolution,' with its mission to digitize the world's books. Such digitization will make the books searchable, thus making participating libraries, such as Stanford University and the University of California Berkley, accessible worldwide. Digital imaging also benefits the medical world because it "allows the electronic transmission of images to third-party providers, referring dentists, consultants, and insurance carriers via a modem The process "is also environmentally friendly since it does not require chemical processing Digital imaging is also frequently used to help document and record historical, scientific and personal life events.

Benefits also exist regarding photographs. Digital imaging will reduce the need for physical contact with original images. Furthermore, digital imaging creates the possibility of reconstructing the visual contents of partially damaged photographs, thus eliminating the potential that the original would be modified or destroyed. In addition, photographers will be "freed from being 'chained' to the darkroom," will have more time to shoot and will be able to cover assignments more effectively. Digital imaging 'means' that "photographers no longer have to rush their film to the office, so they can stay on location longer while still meeting deadlines".

Another advantage to digital photography is that it has been expanded to camera phones. We are able to take cameras with us wherever as well as send photos instantly to others. It is easy for people to us as well as help in the process of self-identification for the younger generation

Drawbacks: Critics of digital imaging cite several negative consequences. An increased “flexibility in getting better quality images to the readers” will tempt editors, photographers and journalists to manipulate photographs. In addition, “staff photographers will no longer be photo journalistists, but camera operators…as editors have the power to decide what they want ‘shot’. Legal constraints, including pose another concern: will copyright infringement occur as documents are digitized and copying becomes easier?

Chapter 2

Dot Matrix

Dot-matrix display: A dot-matrix display is a display device used to display information on machines, clocks, railway departure indicators and many other devices requiring a simple display device of limited resolution.

The display consists of a dot matrix of lights or mechanical indicators arranged in a rectangular configuration (other shapes are also possible, although not common) such that by switching on or off selected lights, text or graphics can be displayed. A dot matrix controller converts instructions from a processor into signals which turns on or off lights in the matrix so that the required display is produced.

Usual resolutions: Common sizes of dot matrix displays:

128×16 (Two lined)

128×32 (Four lined)

128×64 (Eight lined)

Usual character resolutions: A common size for a character is 5×7 pixels, either separated with blank lines with no dots (in most text-only displays), or with lines of blank pixels (making the real size 6x8). This is seen on most graphic calculators, such as Casio calculators or TI-82 and superior.

A smaller size is 3×5 (or 4x6 when separated with blank pixels). This is seen on the TI-80 calculator as a "pure", fixed-size 3×5 font, or on most 7×5 calculators as a proportional (1×5 to 5×5) font. The disadvantage of the 7×5 matrix and smaller is that lower case characters with descenders are not practical. A matrix of 11×9 is often used to give far superior resolution.

Dot matrix displays of sufficient resolution can be programmed to emulate the customary seven-segment numeral patterns.

Detective quantum efficiency: The detective quantum efficiency (often abbreviated as DQE) is a measure of the combined effects of the signal (related to image contrast) and noise performance of an imaging system, generally expressed as a function of spatial frequency. This value is used primarily to describe imaging detectors in optical imaging and medical radiography.

In medical radiography, the DQE describes how effectively an x-ray imaging system can produce an image with a high signal-to-noise ratio (SNR) relative to an ideal detector. It is sometimes viewed to be a surrogate measure of the radiation dose efficiency of a detector since the required radiation exposure to a patient (and therefore the biological risk from that radiation exposure) decreases as the DQE is increased for the same image SNR and exposure conditions.

The DQE is also an important consideration for CCDs, especially those used for low-level imaging in light and electron microscopy, because it affects the SNR of the images. It is also similar to the noise factor used to describe some electronic devices.

FESPA: FESPA is a federation of trade associations and an organiser of exhibitions and conferences for the screen and digital printing industry. Formerly, the name FESPA stood for 'The Federation of European Screen Printers Associations'. With the advent of digital technology, FESPA is known by its acronym.

Fixed pixel displays are display technologies such as LCD and plasma that use an unfluctuating matrix of pixels with a set number of pixels in each row and column. With such displays, adjusting (scaling) to different aspect ratios because of different input signals requires complex processing.

In contrast, the CRTs electronics architecture "paints" the screen with the required number of pixels horizontally and vertically. CRTs can be designed to more easily accommodate a wide range of inputs (VGA, XVGA, NTSC, HDTV, etc.).

LCD crosstalk is a visual defect in an LCD screen which occurs because of interference between adjacent pixels.

Micro Piezo is the brand name of the proprietary piezoelectric inkjet print head technology developed by Japanese imaging company Epson, which is also the only major printing company in the world to use piezoelectric technology throughout its entire inkjet printer range.

Multidimensional systems: By the term multidimensional systems or m-D systems we mean the branch of (mathematical) systems theory where not only one variable exists (like time), but several independent variables. Important problems like factorization and stability have recently attracted the interest of many researchers and practitioners.

Passive matrix addressing is an addressing scheme used in early LCD displays. This is a matrix addressing scheme meaning that only $m + n$ control signals are required to address a $m \times n$ display. A pixel in a passive matrix must maintain its state without active driving circuitry until it can be refreshed again.

The signal is divided into a row or select signal and a column or video signal. The select voltage determines the row that is being addressed and all n pixels on a row are addressed simultaneously. When pixels on a row are being addressed, a Vsel potential is applied, and all other rows are unselected with a Vunsel potential. The video signal or column potential is then applied with a potential for each m columns individually. An on-lighted pixel corresponds to a Von, an off-switched corresponds to a Voff potential.

The potential across pixel at selected row i and column j is

$$V_{ij} = V_{sel} - V_{on|off}$$

and

$$V_{ij} = V_{unsel} - V_{on|off}$$

for the unselected rows.

Passive matrix addressed displays such as ferroelectric liquid crystal displays do not need the switch component of an active matrix display because they have built-in bistability. Technology for electronic paper also has a form of bistability. Displays with bistable pixel elements are addressed with a passive matrix addressing scheme, whereas TFT LCD displays are addressed using active addressing.

The reason is that the factorization and stability of m-D systems (m > 1) is not a straightforward extension of the factorization and stability of 1-D systems because for example the fundamental theorem of algebra does not exist in the ring of m-D (m > 1) polynomials.

Pixel : In digital imaging, a pixel, or pel, (picture element) is a physical point in a raster image, or the smallest addressable element in an all points addressable display device; so it is the smallest controllable element of a picture represented on the screen. The address of a pixel corresponds to its physical coordinates. LCD pixels are manufactured in a two-dimensional grid, and are often represented using dots or squares, but CRT pixels correspond to their timing mechanisms and sweep rates.

Each pixel is a sample of an original image; more samples typically provide more accurate representations of the original. The intensity of each pixel is variable. In color image systems, a color is typically represented by three or four component intensities such as red, green, and blue, or cyan, magenta, yellow, and black.

In some contexts (such as descriptions of camera sensors), the term pixel is used to refer to a single scalar element of a multi-component representation (more precisely called a photosite in the camera sensor context, although the neologism sensel is sometimes used to describe the elements of a digital camera's sensor), while in others the term may refer to the entire set of such component intensities for a spatial position. In color systems that use chroma subsampling, the multi-component concept of a pixel can become difficult to apply, since the intensity measures for the different color components correspond to different spatial areas in such a representation.

The word pixel is based on a contraction of pix ("pictures") and el (for "element"); similar formations with el for "element" include the words voxel and texel.

Pixel aspect ratio (often abbreviated PAR) is a mathematical ratio that describes how the width of a pixel in a digital image compares to the height of that pixel.

Most digital imaging systems display an image as a grid of tiny, square pixels. However, some imaging systems, especially those that must be compatible with standard-definition television motion pictures, display an image as a grid of rectangular pixels, in which the pixel width and height are different. Pixel Aspect Ratio describes this difference.

Use of pixel aspect ratio mostly involves pictures pertaining to standard-definition television and some other exceptional cases. Most other imaging systems, including those that comply with SMPTE standards and practices, use square pixels.

Pixels per centimeter (ppcm), Pixels per inch (PPI) or pixel density is a measurement of the resolution of devices in various contexts: typically computer displays, image scanners, and digital camera image sensors.

Ppcm can also describe the resolution, in pixels, of an image to be printed within a specified space. Note, the unit is not square centimeters. For instance, a 100×100 pixel image that is printed in a 1 cm square has a resolution of 100 pixels per centimeter (ppcm). Used in this way, the measurement is meaningful when printing an image. It has become commonplace to refer to PPI as DPI, which is incorrect because PPI always refers to input resolution. Good quality photographs usually require 300 pixels per inch, at 100% size, when printed onto coated paper stock, using a printing screen of 150 lines per inch (lpi). This delivers a quality factor of 2, which delivers optimum quality. The lowest acceptable quality factor is considered to be 1.5, which equates to printing a 225ppi image using a 150 lpi screen onto coated paper.[citation needed] Screen frequency is determined by the type of paper that the image is to be printed on. An absorbent paper surface, uncoated recycled paper for instance, will allow the droplets of ink to spread (dot gain), and so requires a more open printing screen. Input resolution can therefore be reduced in order to minimise file size without any loss in quality, as long as the quality factor of 2 is maintained. This is easily determined by doubling the line frequency. For example, printing on an uncoated paper stock often limits the printing screen frequency to no more than 120 lpi, therefore, a quality factor of 2 is achieved with images of 240 ppi.

Pixel geometry: The components of the pixels (primary colors red, green and blue) in an image sensor or display can be ordered in different patterns, called pixel geometry.

The geometric arrangement of the primary colors within a pixel varies depending on usage (see figure 1). In monitors, such as LCDs or CRTs, that typically display edges or rectangles, the components are arranged in vertical stripes. Displays with motion pictures should instead have triangular or diagonal patterns so that the image variation is perceived better by the viewer

Polynomial texture mapping, also known as Reflectance Transformation Imaging (RTI), is a technique of imaging and interactively displaying objects under varying lighting conditions to reveal surface phenomena.

Resolution independence is where elements on a computer screen are rendered at sizes independent from the pixel grid, resulting in a graphical user interface that is displayed at a consistent size, regardless of the size of the screen.

Scientific Working Group: The Scientific Working Group on Imaging Technology was convened by the Federal Bureau of Investigation in 1997 to provide guidance to law enforcement agencies and others in the criminal justice system regarding the best practices for photography, videography, and video and image analysis.

Sixteenth HD1080 (or HD1080/16) is a display resolution that is the same aspect ratio and one 16th the area of 1080 line high-definition TV resolution.

HD1080 is 1920×1080 pixels, so dividing the resolution by 4 in each axis gives 480×270 pixels. This is a computationally convenient process, as HD1080 content can be scaled down simply by summing blocks of 16 pixels and dividing by 16 (arithmetic shift right 4 bits).

HD720 is 1280×720 pixels, i.e. 2/3 the resolution of HD1080 in each axis. HD720 content thus needs to be scaled by a factor of 3/8 in each axis, producing 3×3 pixels for every 8×8 pixels in. This is not as easy as scaling HD1080 content.

In practice, these displays are made with 272 rows of pixels where it is more convenient to manufacture pixels in multiples of 8×8. It also helps image compression and decompression, which is commonly done on 8×8 or 16×16 blocks of pixels.

Michael Francis Tompsett is a British born physicist and former researcher at English Electric Valve Company, who later moved to Bell Labs in America. Tompsett designed and built the first ever video camera with a solid-state (CCD) sensor.

Tompsett is known particularly for his work on infrared imagers and CCD imagers. He pioneered compact, low power, high performance and low cost solid-state infrared imagers, CCD imagers and digital cameras and made contributions in several fields with patents and publications over an extended period of time. He claims to be the inventor of the CCD imager, used in devices such as digital cameras.

Chapter 3

General Imaging

General Imaging is a manufacturer of digital cameras headquartered in Torrance, California, established in 2007 by Hiroshi "Hugh" Komiya, a former executive of Olympus Corporation. General Imaging sells their cameras internationally under the General Electric name, used under license. In Japan, General Imaging holds the license to manufacture cameras under the AgfaPhoto.

General Electric, or GE, is an American multinational conglomerate corporation incorporated in Schenectady, New York and headquartered in Fairfield, Connecticut in the United States. The company operates through four divisions: Energy [currently (2013) inactive], Technology Infrastructure, Capital Finance and Consumer and Industrial.

In 2011, GE ranked among the Fortune 500 as the 26th-largest firm in the U.S. by gross revenue, as well as the 14th most profitable. However, the company is currently listed the 4th-largest in the world among the Forbes Global 2000, further metrics being taken into account. Other rankings for 2011/2012 include No. 7 company for leaders (Fortune), No. 5 best global brand (Inter brand), No. 63 green company (Newsweek), No. 15 most admired company (Fortune), and No. 19 most innovative company (Fast Company).

A Series

The entry-level GE-branded digital cameras. Designed for first-time buyers and those upgrading from first-generation digital cameras. Both models in this series include a 2.5-inch LCD screen. Powered by two AA alkaline batteries.

A Series

The A730 is the most affordable point-and-shoot GE-branded camera with 7 megapixels. It has a 3X optical zoom and a 4.5X digital zoom. The LCD screen is 2.5 inches. Powered by two AA batteries, the A730 has an SD/SDHC memory card slot expandable up to 4 gigabytes.

The A830 is a point-and-shoot camera that has all the zoom capabilities and other features of the A730 and comes with 8 megapixels.

E Series:

The intermediate level of the GE-branded camera models, the E series features larger screens and is powered by rechargeable . Memory can be expanded up to 4 gigabytes with SD or SDHC memory cards.

E850

E850

The E850 includes a 28mm equivalent wide-angle lens, a 5X optical zoom and 8 megapixels. The wide-angle lens is useful for large indoor group photos. It has a 5X optical zoom and the 4.5X digital zoom. The camera comes with a 3-inch LCD screen. It also can delete unwanted sections of a photo

E1030*:*

The E1030 has 10 megapixels, a 3X optical zoom and 4.5X digital zoom, which combine for a maximum zoom of 13.5X. The LCD screen is 2.7 inches.

E1040

E1040

The E1040 includes 4X optical zoom, 4.5X digital zoom; and 10 megapixels. 3-inch LCD screen.

E1240

The E1240 features 12 megapixels. A 4X optical zoom and a 4.5X digital zoom combine to create a maximum zoom of 18X; 3-inch LCD screen.

G1

G1

The G1 is the most compact model (3⅝ inches wide and 2½ inches high) in the GE-branded line. It includes a 3X optical zoom, a 2.5-inch LCD screen, 7 megapixels. Comes with a rechargeable lithium-ion battery and an SD/SDHC memory card slot, expandable up to 4 gigabytes.

Waterproof series:

The first GE's waterproof series is G3WP a compact camera with capability for up to 3 meters (10 feet) underwater, 12.2 MP, 4x Optical zoom at 35 mm equivalent lens and VGA Video.[1]

Bridge Cameras

X1

GE X1 is the first high-performance camera from General Imaging for the more serious photographer. It boasts a 12X optical zoom, a 2.5-inch LCD screen, 8 megapixels, and a handgrip. Paired with the camera's 12X optical zoom is a 4.5X digital zoom. Together, they give the X1 a maximum zoom of 54X. It also includes a 4-gigabyte SD/SDHC expansion slot.

GE X5 is the cheapest Bridge camera (dSLR like camera with fixed lens) on the market. On January 4, 2011, the price of Bridge cameras ranged from $129.47 (GE X5: 14 MP CCD sensor, 15x optical zoom) up to $339.95 (Fujifilm Fine Pix HS10: 10.3 MP CMOS sensor, 30x optical zoom), whereas Canon Power Shot SX30 IS: 14.1 MP CCD sensor, 35x optical zoom was $369.00 and Panasonic Lumix DMC-FZ100: 14.1 MP CMOS sensor, 24x optical zoom was only $375.00 (four months before it was $499.00). So, the highest price was almost 3.0x the cheapest price.

GE Power Pro X500 is the successor of GE X5. The camera has a 16-megapixel sensor and an electronic viewfinder, whereas the optical zoom and other features are relatively still the same as the predecessor.[6]

On March 15, 2011 the price of Bridge cameras varied from $139.99 (GE Power Pro X500 White) up to $499.95 (Fujifilm FinePix HS20EXR), whereas Nikon Coolpix P500 is $399.00, Canon Power Shot SX30 IS was $379.00 and Fujifilm HS10 $354.52.So, the highest price was more than 3.5x the cheapest price.

In 2012, GE Power Pro X550 was introduced with (MSRP) $149.99 as a minor improvement on the GE Power Pro X500 with added advanced object tracking capabilities to automatically focus on moving objects. Also introduced then was the GE Power Pro X600 with MSRP $199.99 which has a 14.4 MP CMOS sensor, 25x optical zoom, capable of capturing HD 1080p video recording, and 10 fps continuous images in full resolution. The GE Power Pro X600 is the cheapest with advanced features due to General Imaging continuing commitment to deliver high-performance cameras that give consumers more features and value at unbeatable prices.

Chapter 4

A digital image is a numeric representation

A digital image is a numeric representation (normally binary) of a two-dimensional image. Depending on whether the image resolution is fixed, it may be of vector or raster type. By itself, the term "digital image" usually refers to raster images or bitmapped images.

Binary number: In mathematics and computer science, the binary numeral system, or base-2 numeral system, represents numeric values using two symbols: typically 0 and 1. More specifically, the usual base-2 system is a positional notation with a radix of 2. Numbers represented in this system are commonly called binary numbers. Because of its straightforward implementation in digital electronic circuitry using logic gates, the binary system is used internally by almost all modern computers and computer-based devices such as mobile phones.

Image: An image (from Latin: imago) is an artifact that depicts or records visual perception, for example a two-dimensional picture, that has a similar appearance to some subject – usually a physical object or a person, thus providing a depiction of it.

Image resolution: Image resolution is the detail an image holds. The term applies to raster digital images, film images, and other types of images. Higher resolution means more image detail.

Image resolution can be measured in various ways. Basically, resolution quantifies how close lines can be to each other and still be visibly resolved. Resolution units can be tied to physical sizes (e.g. lines per mm, lines per inch), to the overall size of a picture (lines per picture height, also known simply as lines, TV lines, or TVL), or to angular subtenant. Line pairs are often used instead of lines; a line pair comprises a dark line and an adjacent light line. A line is either a dark line or a light line. A resolution 10 lines per millimeter means 5 dark lines alternating with 5 light lines, or 5 line pairs per millimeter (5 LP/mm). Photographic lens and film resolution are most often quoted in line pairs per millimeter.

Digital image processing is the use of computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems. is the use of computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems.

Image compression: The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form.

Raster: Raster images have a finite set of digital values, called picture elements or pixels. The digital image contains a fixed number of rows and columns of pixels. Pixels are the smallest individual element in an image, holding quantized values that represent the brightness of a given color at any specific point.

Typically, the pixels are stored in computer memory as a raster image or raster map, a two-dimensional array of small integers. These values are often transmitted or stored in a compressed form.

Raster images can be created by a variety of input devices and techniques, such as digital cameras, scanners, coordinate-measuring machines, seismographic profiling, airborne radar, and more. They can also be synthesized from arbitrary non-image data, such as mathematical functions or three-dimensional geometric models; the latter being a major sub-area of computer graphics. The field of digital image processing is the study of algorithms for their transformation.

Raster file formats: Most users come into contact with raster images through digital cameras, which use any of several image file formats. Some digital cameras give access to almost all the data captured by the camera, using a raw image format. The Universal Photographic Imaging Guidelines (UPDIG) suggests these formats be used when possible since raw files produce the best quality images. These file formats allow the photographer and the processing agent the greatest level of control and accuracy for output. Their use is inhibited by the prevalence of proprietary information (trade secrets) for some camera makers, but there have been initiatives such as Open RAW to influence manufacturers to release these records publicly. An alternative may be Digital Negative (DNG), a proprietary Adobe product described as “the public, archival format for digital camera raw data, Although this format is not yet universally accepted, support for the product is growing, and increasingly professional archivists and conservationists, working for respectable organizations, variously suggest or recommend DNG for archival purposes

A digital camera (or digicam) is a camera that encodes digital images and videos digitally and stores them for later reproduction. Most cameras sold today are digital, and digital cameras are incorporated into many devices ranging from PDAs and mobile phones (called camera phones) to vehicles.

Digital and film cameras share an optical system, typically using a lens with a variable diaphragm to focus light onto an image pickup device. The diaphragm and shutter admit the correct amount of light to the imager, just as with film but the image pickup device is electronic rather than chemical. However, unlike film cameras, digital cameras can display images on a screen immediately after being recorded, and store and delete images from memory. Many digital cameras can also record moving video with sound. Some digital cameras can crop and stitch pictures and perform other elementary image editing.

Vector: Vector images resulted from mathematical geometry (vector). In mathematical terms, a vector consists of point that has both direction and length. Often, both raster and vector elements will be combined in one image; for example, in the case of a billboard with text (vector) and photographs (raster).

Vector graphics is the use of geometrical primitives such as points, lines, curves, and shapes or polygon(s), which are all based on mathematical expressions, to represent images in computer graphics. Vector graphics are based on vectors (also called paths, or strokes) which lead through locations called control points. Each of these points has a definite position on the x and y axes of the work plan. Each point, as well, is a variety of database, including the location of the point in the work space and the direction of the vector (which is what defines the direction of the track). Each track can be assigned a color, a shape, a thickness and also a fill.

This does not affect the size of the files in a substantial way because all information resides in the structure; it describes how to draw the vector.

Image viewing: Image viewer software displays images. Web browsers can display standard internet image formats including GIF, JPEG, and PNG. Some can show SVG format which is a standard W3C format. Some viewers offer a slideshow utility to display a sequence of images.

Image viewing or image browser is a computer program that can display stored graphical images; it can often handle various graphics file formats. Such software usually renders the image according to properties of the display such as color depth, display resolution, and color profile.

Although one may use a full-featured bitmap graphics editor (such as Photoshop or the GIMP or the StylePix) as an image viewer, these have many editing functionalities which are not needed for just viewing images, and therefore usually start rather slowly. Also, most viewers have functionalities that editors usually lack, such as stepping through all the images in a directory (possibly as a slideshow).

Image viewers give maximal flexibility to the user by providing a direct view of the directory structure available on a hard disk. Most image viewers do not provide any kind of automatic organization of pictures and therefore the burden remains on the user to create and maintain their folder structure (using tag- or folder-based methods). However, some image viewers also have features for organizing images, especially an image database, and hence can also be used as image organizers.

Some image viewers, such as Windows Photo Viewer that comes with Windows operating systems, change a JPEG image if it is rotated, resulting in loss of image quality; others offer lossless rotation.

web browser : A web browser (commonly referred to as a browser) is a software application for retrieving, presenting and traversing information resources on the World Wide Web. An information resource is identified by a Uniform Resource Identifier (URI/URL) and may be a web page, image, video or other piece of content.Hyperlinks present in resources enable users easily to navigate their browsers to related resources.

Although browsers are primarily intended to use the World Wide Web, they can also be used to access information provided by web servers in private networks or files in file systems.

The major web browsers are Google Chrome, Mozilla Firefox, Internet Explorer, Opera, and Safari.

Graphics Interchange Format: The Graphics Interchange Format (better known by its acronym GIF; is a bitmap image format that was introduced by CompuServe in 1987 and has since come into widespread usage on the World Wide Web due to its wide support and portability.

The format supports up to 8 bits per pixel for each image, allowing a single image to reference its own palette of up to 256 different colors chosen from the 24-bit RGB color space. It also supports animations and allows a separate palette of up to 256 colors for each frame. These palette limitations make the GIF format unsuitable for reproducing color photographs and other images with continuous color, but it is well-suited for simpler images such as graphics or logos with solid areas of color.

GIF images are compressed using the Lempel-Ziv-Welch (LZW) lossless data compression technique to reduce the file size without degrading the visual quality. This compression technique was patented in 1985. Controversy over the licensing agreement between the software patent holder, Unisys, and CompuServe in 1994 spurred the development of the Portable Network Graphics (PNG) standard. All the relevant patents have now expired.

JPEG : In computing, JPEG - named after its creator the Joint Photographic Expert Group - (jay-peg) (seen most often with the .jpg extension) is a commonly used method of lossy compression for digital photography (i.e. images). The degree of compression can be adjusted, allowing a selectable tradeoff between storage size and image quality. JPEG typically achieves 10:1 compression with little perceptible loss in image quality, and is the file type most often produced in digital photography.

JPEG compression is used in a number of image file formats. JPEG/Exif is the most common image format used by digital cameras and other photographic image capture devices; along with JPEG/JFIF, it is the most common format for storing and transmitting photographic images on the World Wide Web These format variations are often not distinguished, and are simply called JPEG.

The term "JPEG" is an acronym for the Joint Photographic Experts Group, which created the standard. The MIME media type for JPEG is image/jpeg (defined in RFC 1341), except in Internet Explorer, which provides a MIME type of image/pjpeg when uploading JPEG images.

Portable Network Graphics (PNG ping), or PNG's Not GIF, is a raster graphics file format that supports lossless data compression. PNG was created as an improved, non-patented replacement for Graphics Interchange Format (GIF), and is the most used lossless image compression format on the Internet.

PNG supports palette-based images (with palettes of 24-bit RGB or 32-bit RGBA colors), grayscale images (with or without alpha channel), and full-color non-palette-based RGB A images (with or without alpha channel). PNG was designed for transferring images on the Internet, not for professional-quality print graphics, and therefore does not support non-RGB color spaces such as CMYK.

PNG files nearly always use file extension PNG or png and are assigned MIME media type image/png. PNG was approved for this use by the Internet Engineering Steering Group on 14 October 1996, and was published as an ISO/IEC standard in 2004.

Scalable Vector Graphics (SVG) is an XML-based vector image format for two-dimensional graphics that has support for interactivity and animation. The SVG specification is an open standard developed by the World Wide Web Consortium (W3C) since 1999.

SVG images and their behaviors are defined in XML text files. This means that they can be searched, indexed, scripted, and, if need be, compressed. As XML files, SVG images can be created and edited with any text editor, but it is often more convenient to create them with drawing programs such as Inkscape.

All major modern web browsers—including Mozilla Firefox, Internet Explorer 9 and 10, Google Chrome, Opera, and Safari—have at least some degree of support for SVG and can render the markup directly.

The World Wide Web Consortium (W3C) is the main international standards organization for the World Wide Web (abbreviated WWW or W3).

Founded and currently led by Tim Berners-Lee, the consortium is made up of member organizations which maintain full-time staff for the purpose of working together in the development of standards for the World Wide Web. As of 7 September 2013, the World Wide Web Consortium (W3C) has 383 members.

W3C also engages in education and outreach, develops software and serves as an open forum for discussion about the Web.

History: Early Digital fax machines such as the Bartlane cable picture transmission system preceded digital cameras and computers by decades. The first picture to be scanned, stored, and recreated in digital pixels was displayed on the Standards Eastern Automatic Computer (SEAC) at NIST. The advancement of digital imagery continued in the early 1960s, alongside development of the space program and in medical research. Projects at the Jet Propulsion Laboratory, MIT, Bell Labs and the University of Maryland, among others, used digital images to advance satellite imagery, wirephoto standards conversion, medical imaging, videophone technology, character recognition, and photo enhancement.

Rapid advances in digital imaging began with the introduction of microprocessors in the early 1970s, alongside progress in related storage and display technologies. The invention of computerized axial tomography (CAT scanning), using x-rays to produce a digital image of a "slice" through a three-dimensional object, was of great importance to medical diagnostics. As well as origination of digital images, digitization of analog images allowed the enhancement and restoration of archaeological artifacts and began to be used in fields as diverse as nuclear medicine, astronomy, law enforcement, defence and industry.

Advances in microprocessor technology paved the way for the development and marketing of charge-coupled devices (CCDs) for use in a wide range of image capture devices and gradually displaced the use of analog film and tape in photography and videography towards the end of the 20th century. The computing power necessary to process digital image capture also allowed computer-generated digital images to achieve a level of refinement close to photorealism.

Chapter 5

Category Digital Imaging

Digital imaging or digital image acquisition is the creation of digital images, typically from a physical scene. The term is often assumed to imply or include the processing, compression, storage, printing, and display of such images. The most usual method is by digital photography with a digital camera but other methods are also employed.

1:1 Pixel Mapping is a video display technique used in some devices, such as LCD monitors. A monitor that has been set to 1:1 pixel mapping will try to display an input source without scaling it, such that each pixel received is mapped to a single native pixel on the monitor. This will result in a black border around the image (window boxing) unless the input resolution is greater than or equal to the monitor's native resolution. This technique is helpful if it is desired to stop a video from being stretched or distorted by the monitor.

2K resolution is a generic term for display devices or content having horizontal resolution on the order of 2,000 pixels.

In the movie projection industry, Digital Cinema Initiatives is the dominant 2K standard. In television, the top-end 1080p high-definition television format qualifies as 2K resolution, having a horizontal resolution of 1920 pixels, with a vertical resolution of 1080 pixels.

Resolutions:

Format	**Resolution**	**Display aspect ratio**	**Pixels**
Digital Cinema Initiatives 2K (native resolution)	2048 × 1080	1.90:1 (256:135) ~17:9	2,211,840

DCI 2K (CinemaScope cropped)	2048 × 858	2.39:1	1,755,136
DCI 2K (flat cropped)	1998 × 1080	1.85:1 (21:9)	2,157,840
1080p HDTV	1920 × 1080	1.78:1 (16:9)	2,073,600
1440p (sometimes marketed as "2K HD")	2560 × 1440	1.78:1 (16:9)	3,686,400
1600p, aka WQXGA (supported by several 30" monitors, Mac and tablets)	2560 × 1600	1.60:1 (16:10)	4,096,000

3LCD is the name and brand of a major LCD projection color image generation technology used in modern digital projectors. 3LCD technology was developed and refined by Japanese imaging company Epson in the 1980s and was first licensed for use in projectors in 1988. In January 1989, Epson launched its first 3LCD projector, the VPJ-700.

Although Epson still owns 3LCD technology, it is marketed by an affiliated organization simply named after the technology:"3LCD". The organization is a consortium of projector manufacturers that have licensed 3LCD technology to be used in their products. To date, about 40 different projector brands worldwide have adopted 3LCD technology.

According to electronics industry research company Pacific Media Associates, projectors using 3LCD technology comprised about 51% of the world's digital projector market in 2009.

3LCD technology gets its name from the three LCD panel chips used in its image generation engine.

4K resolution is a generic term for display devices or content having horizontal resolution on the order of 4,000 pixels. Several 4K resolutions exist in the fields of digital television and digital cinematography. In the movie projection industry, Digital Cinema Initiatives is the dominant 4K standard.

The television industry has adopted ultra high definition television as its 4K standard. As of 2013, some UHDTV models are available to general consumers for under $1000. However, due to lack of available content, 4K television has yet to achieve mass market appeal. Using horizontal resolution to characterize the technology marks a switch from the previous generation, high definition television, which categorized media according to vertical resolution (1080i, 720p, 480p, etc.). The top-end regular HDTV format, 1080p, qualifies as 2K resolution, having a horizontal resolution of 1920 pixels, with a vertical resolution of 1080 pixels.

8K resolutions: Several 8K resolutions exist in digital television and digital cinematography. The term 8K refers to the horizontal resolution of these formats, which are all on the order of 8,000 pixels.

resolutions

7680 × 4320 (16:9) (33.1 megapixels)

7680 x 4800 (16:10) (36.8 megapixels)

8192 × 4320 (~17:9) (35.3 megapixels)

8192 × 8192 (1:1) (67.1 megapixels)

8K UHD is a resolution of 7680 × 4320 (33.1 megapixels) and is one of the two resolutions of ultra high definition television, the other being 4K UHD. In 2013, a transmission network's capability to carry HDTV resolution was limited by internet speeds and relied on satellite broadcast to transmit the high data rates. The demand is expected to drive the adoption of video compression standards and to place significant pressure on physical communication networks in the near future.

8K UHD has four times the horizontal and vertical resolution of the 1080p HDTV format, with sixteen times as many pixels overall. Example:

width: 1920 × 4 = 7680

height: 1080 × 4 = 4320

8K UHD (7680×4320 = 33,177,600 pixels)			
1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)
1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)
1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)
1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)	1080p (1920×1080)

Color Light Output: Color Light Output also known as Color Brightness, or CLO is a specification that provides information on a projector’s ability to reproduce color. Color Light Output is specified in the lumen unit and measures a color projection system's ability to correctly reproduce color brightness.

Color mapping: Color mapping is a function that maps (transforms) the colors of one (source) image to the colors of another (target) image. A color mapping may be referred to as the algorithm that results in the mapping function or the algorithm that transforms the image colors.

Color mapping is also sometimes called color transfer or, when grayscale images are involved, brightness transfer function (BTF)

Computer display standards: Computer display standards are often a combination of aspect ratio, display

Defective pixels: Defective pixels are pixels on a liquid crystal display (LCD) that are not performing as expected. The ISO standard ISO 13406-2 distinguishes between three different types of defective pixels, while hardware companies tend to have further distinguishing types. Similar defects can also occur in a charge-coupled device (CCD) or CMOS image sensor in digital cameras. In these devices, defective pixels fail to sense light levels correctly, whereas defective pixels in LCDs fail to reproduce light levels correctly

Digital photo frame: A digital photo frame (also called a digital media frame) is a picture frame that displays digital photos without the need of a computer or printer. The introduction of digital photo frames predates tablet computers, which can serve the same purpose in some situations, however, digital photo frames are generally designed specifically for the stationary, aesthetic display of photographs and therefore usually provide a nicer-looking frame and a power system designed for continuous use.

Digital photo frames come in a variety of different shapes and sizes with a range of features. Some may even play videos as well as display photographs.

Display resolution: The display resolution of a digital television, computer monitor or display device is the number of distinct pixels in each dimension that can be displayed. It can be an ambiguous term especially as the displayed resolution is controlled by different factors in cathode ray tube (CRT), Flat panel display which includes Liquid crystal displays, or projection displays using fixed picture-element (pixel) arrays.

It is usually quoted as width × height, with the units in pixels: for example, "1024 × 768" means the width is 1024 pixels and the height is 768 pixels. This example would normally be spoken as "ten twenty-four by seven sixty-eight" or "ten twenty-four by seven six eight".

One use of the term “display resolution” applies to fixed-pixel-array displays such as plasma display panels (PDPs), liquid crystal displays (LCDs), digital light processing (DLP) projectors, or similar technologies, and is simply the physical number of columns and rows of pixels creating the display (e.g., 1920 × 1080). A consequence of having a fixed-grid display is that, for multi-format video inputs, all displays need a "scaling engine" (a digital video processor that includes a memory array) to match the incoming picture format to the display.

Note that for broadcast television standards the use of the word resolution here is a misnomer, though common. The term “display resolution” is usually used to mean pixel dimensions, the number of pixels in each dimension (e.g., 1920 × 1080), which does not tell anything about the pixel density of the display on which the image is actually formed: broadcast television resolution properly refers to the pixel density, the number of pixels per unit distance or area, not total number of pixels. In digital measurement, the display resolution would be given in pixels per inch. In analog measurement, if the screen is 10 inches high, then the horizontal resolution is measured across a square 10 inches wide. This is typically stated as "lines horizontal resolution, per picture height; for example, analog NTSC TVs can typically display about 340 lines of "per picture height" horizontal resolution from over-the-air sources, which is equivalent to about 440 total lines of actual picture information from left edge to right edge.

Dot matrix: A dot matrix is a 2-dimensional patterned array, used to represent characters, symbols and images. Every type of modern technology uses dot matrices for display of information, including cell phones, televisions, and printers. They are also used in textiles with sewing, knitting, and weaving.

An alternate form of information display using lines and curves is known as a vector display, was used with early computing devices such as air traffic control radar displays and pen-based plotters but is no longer used. Electronic vector displays were typically monochrome only, and either don't fill in the interiors of closed vector shapes, or shape-filling is slow, time-consuming, and often non-uniform, as on pen-based plotters.

In printers, the dots are usually the darkened areas of the paper. In displays, the dots may light up, as in an LED, CRT, or plasma display, or darken, as in an LCD.

Chapter 6

Channel (Digital Image II)

Color digital images are made of pixels, and pixels are made of combinations of primary colors. A channel in this context is the grayscale image of the same size as a color image, made of just one of these primary colors. For instance, an image from a standard digital camera will have a red, green and blue channel. A grayscale image has just one channel.

Pixel: In digital imaging, a pixel, or pel, (picture element) is a physical point in a raster image, or the smallest addressable element in an all points addressable display device; so it is the smallest controllable element of a picture represented on the screen. The address of a pixel corresponds to its physical coordinates. LCD pixels are manufactured in a two-dimensional grid, and are often represented using dots or squares, but CRT pixels correspond to their timing mechanisms and sweep rates.

Each pixel is a sample of an original image; more samples typically provide more accurate representations of the original. The intensity of each pixel is variable. In color image systems, a color is typically represented by three or four component intensities such as red, green, and blue, or cyan, magenta, yellow, and black.

In some contexts (such as descriptions of camera sensors), the term pixel is used to refer to a single scalar element of a multi-component representation (more precisely called a photosite in the camera sensor context, although the neologism sensel is sometimes used to describe the elements of a digital camera's sensor), while in others the term may refer to the entire set of such component intensities for a spatial position. In color systems that use chroma subsampling, the multi-component concept of a pixel can become difficult to apply, since the intensity measures for the different color components correspond to different spatial areas in such a representation.

The word pixel is based on a contraction of pix ("pictures") and el (for "element"); similar formations with el for "element" include the words voxel and texel.

Primary colors are sets of colors that can be combined to make a useful range of colors. For human applications, three primary colors are usually used, since human color vision is trichromatic.

For additive combination of colors, as in overlapping projected lights or in CRT displays, the primary colors normally used are red, green, and blue. For subtractive combination of colors, as in mixing of pigments or dyes, such as in printing, the primaries normally used are cyan, magenta, and yellow, though the set of red, yellow, blue is popular among artists. See RGB color model, CMYK color model, and RYB color model for more on these popular sets of primary colors.

Any particular choice for a given set of primary colors is derived from the spectral sensitivity of each of the human cone photoreceptors; three colors that fall within each of the sensitivity ranges of each of the human cone cells are red, green, and blue. Other sets of colors can be used, though not all will well approximate the full range of color perception. For example, an early color photographic process, autochrome, typically used orange, green, and violet primaries. However, unless negative amounts of a color are allowed the gamut will be restricted by the choice of primaries.

The combination of any two primary colors creates a secondary color.

The most commonly used additive color primaries are the secondary colors of the most commonly used subtractive color primaries, and vice versa.

Overview

In the digital realm, there can be any number of conventional primary colors making up an image; a channel in this case is extended to be the grayscale image based on any such conventional primary color. By extension, a channel is any grayscale image the same size with the "proper" image, and associated with it.

"Channel" is a conventional term used to refer to a certain component of an image. In reality, any image format can use any algorithm internally to store images. For instance, GIF images actually refer to the color in each pixel by an index number, which refers to a table where three color components are stored. However, regardless of how a specific format stores the images, discrete color channels can always be determined, as long as a final color image can be rendered.

The concept of channels is extended beyond the visible spectrum in multispectral and hyperspectral imaging. In that context, each channel corresponds to a range of wavelengths and contains spectroscopic information. The channels can have multiple widths and ranges.

Three main channel types (or color models) exist, and have respective strengths and weaknesses.

RGB: An RGB image has three channels: red, green, and blue. RGB channels roughly follow the color receptors in the human eye, and are used in computer displays and image scanners.

If the RGB image is 24-bit (the industry standard as of 2005), each channel has 8 bits, for red, green, and blue—in other words, the image is composed of three images (one for each channel), where each image can store discrete pixels with conventional brightness intensities between 0 and 255. If the RGB image is 48-bit (very high resolution), each channel is made of 16-bit images.

RGB color model: The RGB color model is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, red, green, and blue.

The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems, such as televisions and computers, though it has also been used in conventional photography. Before the electronic age, the RGB color model already had a solid theory behind it, based in human perception of colors.

RGB is a device-dependent color model: different devices detect or reproduce a given RGB value differently, since the color elements (such as phosphors or dyes) and their response to the individual R, G, and B levels vary from manufacturer to manufacturer, or even in the same device over time. Thus an RGB value does not define the same color across devices without some kind of color management.

Typical RGB input devices are color TV and video cameras, image scanners, and digital cameras. Typical RGB output devices are TV sets of various technologies (CRT, LCD, plasma, etc.), computer and mobile phone displays, video projectors, multicolor LED displays, and large screens such as JumboTron. Color printers, on the other hand, are not RGB devices, but subtractive color devices (typically CMYK color model).

This article discusses concepts common to all the different color spaces that use the RGB color model, which are used in one implementation or another in color image-producing technology.

RGB color sample

- 

  A 24-bit RGB image

- 

  The RED channel of the original RGB image (converted to greyscale for easier viewing)

- 

  The GREEN channel of the original RGB image (converted to greyscale for easier viewing)

- 

  The BLUE channel of the original RGB image (converted to greyscale for easier viewing)

Notice how the grey trees have similar brightness in all channels, the red dress is much brighter in the red channel than in the other two, and how the green part of the picture is shown much brighter in the green channel.

CMYK: A CMYK image has four channels: cyan, magenta, yellow, and black. CMYK is the standard for print, where subtractive coloring is used.

A 32-bit CMYK image (the industry standard as of 2005) is made of four 8-bit channels, one for cyan, one for magenta, one for yellow, and one for key color (typically is black). 64-bit storage for CMYK images (16-bit per channel) is not common, given the fact that CMYK is usually device-dependent, whereas RGB is the generic standard for device-independent storage.

CMYK color model : The CMYK color model (process color, four color) is a subtractive color model, used in color printing, and is also used to describe the printing process itself. CMYK refers to the four inks used in some color printing: cyan, magenta, yellow, and key (black). Though it varies by print house, press operator, press manufacturer, and press run, ink is typically applied in the order of the abbreviation.

The "K" in CMYK stands for key because in four-color printing, cyan, magenta, and yellow printing plates are carefully keyed, or aligned, with the key of the black key plate. Some sources suggest that the "K" in CMYK comes from the last letter in "black" and was chosen because B already means blue. The CMYK model works by partially or entirely masking colors on a lighter, usually white, background. The ink reduces the light that would otherwise be reflected. Such a model is called subtractive because inks "subtract" brightness from white.

In additive color models such as RGB, white is the "additive" combination of all primary colored lights, while black is the absence of light. In the CMYK model, it is the opposite: white is the natural color of the paper or other background, while black results from a full combination of colored inks. To save money on ink, and to produce deeper black tones, unsaturated and dark colors are produced by using black ink instead of the combination of cyan, magenta and yellow.

CMYK color sample

> *As of 2011, the 32-bit CMYK image won't be displayed by some major browsers. The RGB image from above is substituted in its place with the link below it. Try saving the link to disk and opening it in another program if it will not display in your browser.*

- 

  A 32-bit CMYK image

- 

  The CYAN channel of the original CMYK image

- 

  The MAGENTA channel of the original CMYK image

- 

  The YELLOW channel of the original CMYK image

- 

  The KEY (black) channel of the original CMYK image

HSV, or Hue Saturation Value, stores color information in three channels, just like RGB, but one channel is devoted to brightness (Value), and the other two convey colour information. The value channel is exactly the same as the CMYK Black channel, or its negative.

HSV is especially useful in lossy video compression, where loss of color information is less noticeable to the human eye. See Optimized channel sizes below.

Alpha channel: The alpha channel stores transparency information—the higher the value, the more opaque that pixel is. No camera or scanner measures transparency, although physical objects certainly can possess transparency, but the alpha channel is extremely useful for compositing digital images together.

Blue screen technology involves filming actors in front of a primary color background, then setting that color to transparent, and compositing it with a background.

The GIF and PNG image formats use alpha channels on the World Wide Web to merge images on web pages so that they appear to have an arbitrary shape even on a non-uniform background.

Bit depth: In digitizing images, the color channels are converted to numbers. Since images contain thousands of pixels, each with multiple channels, channels are usually encoded in as few bits as possible. Typical values are 8 bits per channel or 16 bits per channel. Indexed color effectively gets rid of channels altogether to get, for instance, 3 channels into 8 bits (GIF) or 16 bits.

Optimized channel sizes: Since the brain doesn't necessarily perceive distinctions in each channel to the same degree as in other channels, it is possible that differing the number of bits allocated to each channel will result in more optimal storage; in particular, for RGB images, compressing the blue channel the most and the red channel the least may be better than giving equal space to each. This type of "preferential" compression is the result of studies which show that the human retina actually uses the red channel to distinguish detail along with the green channel in a lesser measure, and uses the blue channel for background or environmental information.

Among other techniques, lossy video compression uses Chroma subsampling to reduce the bit depth in color channels (Hue and Saturation), while keeping all brightness information (Value in HSV).

16-bit HiColor stores red and blue in 5 bits, and green in 6 bits.

Chapter 7

Image

An image (from Latin: imago) is an artifact that depicts or records visual perception, for example a two-dimensional picture, that has a similar appearance to some subject – usually a physical object or a person, thus providing a depiction of it.

Characteristics: Images may be two-dimensional, such as a photograph, screen display, and as well as a three-dimensional, such as a statue or hologram. They may be captured by optical devices – such as cameras, mirrors, lenses, telescopes, microscopes, etc. and natural objects and phenomena, such as the human eye or water surfaces.

The word image is also used in the broader sense of any two-dimensional figure such as a map, a graph, a pie chart, or an abstract painting. In this wider sense, images can also be rendered manually, such as by drawing, painting, carving, rendered automatically by printing or computer graphics technology, or developed by a combination of methods, especially in a pseudo-photograph.

A volatile image is one that exists only for a short period of time. This may be a reflection of an object by a mirror, a projection of a camera obscura, or a scene displayed on a cathode ray tube. A fixed image, also called a hard copy, is one that has been recorded on a material object, such as paper or textile by photography or any other digital process.

A mental image exists in an individual's mind. Like something one remembers or imagines. The subject of an image need not be real; it may be an abstract concept, such as a graph, function, or "imaginary" entity. For example, Sigmund Freud claimed to have dreamed purely in aural-images of dialogs. The development of synthetic acoustic technologies and the creation of sound art have led to a consideration of the possibilities of a sound-image made up of irreducible phonic substance beyond linguistic or musicological analysis.

A still image is a single static image, as distinguished from a kinetic image (see below). This phrase is used in photography, visual media and the computer industry to emphasize that one is not talking about movies, or in very precise or pedantic technical writing such as a standard.

A film still is a photograph taken on the set of a movie or television program during production, used for promotional purposes.

Dimension (mathematics and physics): In physics and mathematics, the dimension of a space or object is informally defined as the minimum number of coordinates needed to specify any point within it. Thus a line has a dimension of one because only one coordinate is needed to specify a point on it (for example, the point at 5 on a number line). A surface such as a plane or the surface of a cylinder or sphere has a dimension of two because two coordinates are needed to specify a point on it (for example, to locate a point on the surface of a sphere you need both its latitude and its longitude). The inside of a cube, a cylinder or a sphere is three-dimensional because three coordinates are needed to locate a point within these spaces.

In physical terms, dimension refers to the constituent structure of all space (cf. volume) and its position in time (perceived as a scalar dimension along the t-axis), as well as the spatial constitution of objects within—structures that correlate with both particle and field conceptions, interact according to relative properties of mass—and are fundamentally mathematical in description. These, or other axes, may be referenced to uniquely identify a point or structure in its attitude and relationship to other objects and occurrences. Physical theories that incorporate time, such as general relativity, are said to work in 4-dimensional "space time", (defined as a Minkowski space). Modern theories tend to be "higher-dimensional" including quantum field and string theories. The state-space of quantum mechanics is an infinite-dimensional function space.

The concept of dimension is not restricted to physical objects. High-dimensional spaces occur in mathematics and the sciences for many reasons, frequently as configuration spaces such as in Lagrangian or Hamiltonian mechanics; these are abstract spaces, independent of the physical space we live in.

Photograph: A photograph or photo is an image created by light falling on a light-sensitive surface, usually photographic film or an electronic image such as a CCD or a CMOS chip. Most photographs are created using a camera, which uses a lens to focus the scene's visible wavelengths of light into a reproduction of what the human eye would see. The process and practice of creating photographs is called photography. The word "photograph" was coined in

1839 by Sir John Herschel and is based on the Greek φῶς (phos), meaning "light", and γραφή (graphê), meaning "drawing, writing", together meaning "drawing with light".

Statue: A statue is a sculpture representing one or more people or animals (including abstract concepts allegorically represented as people or animals), normally full-length, as opposed to a bust, and at least close to life-size, or larger. A small statue, usually small enough to be picked up, is called a statuette or figurine.

The definition of a statue is not always clear-cut; equestrian statues, of a person on a horse, are certainly included, and in many cases, such as a Madonna and Child or a Pietà, a sculpture of two people will also be.

Statues have been produced in many cultures from prehistory to the present; the oldest known statue dating to about 30,000 years ago. The world's tallest statue is over 500 feet.

Many statues are built on commission to commemorate a historical event, or the life of an influential person. Many statues are intended as public art, exhibited outdoors or in public buildings. Some statues gain fame in their own right, separate from the person or concept they represent, as with the Statue of Liberty.

Holography is a technique which enables three-dimensional images to be made. It involves the use of a laser, interference, diffraction, light intensity recording and suitable illumination of the recording. The image changes as the position and orientation of the viewing system changes in exactly the same way as if the object were still present, thus making the image appear three-dimensional.

The holographic recording itself is not an image; it consists of an apparently random structure of either varying intensity, density or profile.

Optics is the branch of physics which involves the behaviour and properties of light, including its interactions with matter and the construction of instruments that use or detect it. Optics usually describes the behaviour of visible, ultraviolet, and infrared light. Because light is an electromagnetic wave, other forms of electromagnetic radiation such as X-rays, microwaves, and radio waves exhibit similar properties.

Most optical phenomena can be accounted for using the classical electromagnetic description of light. Complete electromagnetic descriptions of light are, however, often difficult to apply in practice. Practical optics is usually done using simplified models. The most common of these, geometric optics, treats light as a collection of rays that travel in straight lines and bend when they pass through or reflect from surfaces. Physical optics is a more comprehensive model of light, which includes wave effects such as diffraction and interference that cannot be accounted for in geometric optics. Historically, the ray-based model of light was developed first, followed by the wave model of light. Progress in electromagnetic theory in the 19th century led to the discovery that light waves were in fact electromagnetic radiation.

Some phenomena depend on the fact that light has both wave-like and particle-like properties. Explanation of these effects requires quantum mechanics. When considering light's particle-like properties, the light is modelled as a collection of particles called "photons". Quantum optics deals with the application of quantum mechanics to optical systems.

Optical science is relevant to and studied in many related disciplines including astronomy, various engineering fields, photography, and medicine (particularly ophthalmology and optometry). Practical applications of optics are found in a variety of technologies and everyday objects, including mirrors, lenses, telescopes, microscopes, lasers, and fibre optics.

Camera obscura:The camera obscura (Latin; camera for "vaulted chamber/room", obscura for "dark", together "darkened chamber/room"; plural: camera obscuras or camerae obscurae) is an optical device that projects an image of its surroundings on a screen. It is used in drawing and for entertainment, and was one of the inventions that led to photography and the camera. The device consists of a box or room with a hole in one side. Light from an external scene passes through the hole and strikes a surface inside, where it is reproduced, rotated 180 degrees (thus upside-down), but with color and perspective preserved. The image can be projected onto paper, and can then be traced to produce a highly accurate representation.The largest camera obscura in the world is on Constitution Hill in Aberystwyth, Wales.

Using mirrors, as in the 18th-century overhead version (illustrated in the History section below), it is possible to project a right-side-up image. Another more portable type is a box with an angled mirror projecting onto tracing paper placed on the glass top, the image being upright as viewed from the back.

As the pinhole is made smaller, the image gets sharper, but the projected image becomes dimmer. With too small a pinhole, however, the sharpness worsens, due to diffraction. Some practical camera obscuras use a lens rather than a pinhole because it allows a larger aperture, giving a usable brightness while maintaining focus. (See pinhole camera for construction information.

Cathode ray tube: The cathode ray tube (CRT) is a vacuum tube containing one or more electron guns (a source of electrons or electron emitter) and a fluorescent screen used to view images. It has a means to accelerate and deflect the electron beam(s) onto the screen to create the images. The images may represent electrical waveforms (oscilloscope), pictures (television, computer monitor), radar targets or others. CRTs have also been used as memory devices, in which case the visible light emitted from the fluoresecent material (if any) is not intended to have significant meaning to a visual observer (though the visible pattern on the tube face may cryptically represent the stored data).

The CRT uses an evacuated glass envelope which is large, deep (i.e. long from front screen face to rear end), fairly heavy, and relatively fragile. As a matter of safety, the face is typically made of thick lead glass so as to be highly shatter-resistant and to block most X-ray emissions, particularly if the CRT is used in a consumer product.

CRTs have largely been superseded by newer display technologies such as LCD, plasma display, and OLED, which have lower manufacturing costs, power consumption, weight and bulk.

The vacuum level inside the tube is high vacuum on the order of 0.01 Pa to 133 nPa.

In television sets and computer monitors, the entire front area of the tube is scanned repetitively and systematically in a fixed pattern called a raster. An image is produced by controlling the intensity of each of the three electron beams, one for each additive primary color (red, green, and blue) with a video signal as a reference. In all modern CRT monitors and televisions, the beams are bent by magnetic deflection, a varying magnetic field generated by coils and driven by electronic circuits around the neck of the tube, although electrostatic deflection is commonly used in oscilloscopes, a type of diagnostic instrument.

Mental image: A mental image is the representation in your mind of the physical world outside of you. It is an experience that, on most occasions, significantly resembles the experience of perceiving some object, event, or scene, but occurs when the relevant object, event, or scene is not actually present to the senses. There are sometimes episodes, particularly on falling asleep (hypnagogic imagery) and waking up (hypnopompic), when the mental imagery, being of a rapid, phantasmagoric and involuntary character, defies perception, presenting a kaleidoscopic field, in which no distinct object can be discerned.

The nature of these experiences, what makes them possible, and their function (if any) have long been subjects of research and controversy in philosophy, psychology, cognitive science, and more recently, neuroscience. As contemporary researchers use the expression, mental images (or mental imagery) can occur in the form of any sense, so that we may experience auditory images olfactory images and so forth. However, the vast majority of philosophical and scientific investigations of the topic focus upon visual mental imagery. It has been assumed that, like humans, many types of animals are capable of experiencing mental images. Due to the fundamentally subjective nature of the phenomenon, there is little to no evidence either for or against this view.

Philosophers such as George Berkeley and David Hume, and early experimental psychologists such as Wilhelm Wundt and William James, understood ideas in general to be mental images. Today it is very widely believed that much imagery functions as mental representations (or mental models), playing an important role in memory and thinking. William Brant (2013, p. 12) traces the scientific use of the phrase "mental images" back to the William Tyndall's 1870 speech called the "Scientific Use of the Imagination." Some have gone so far as to suggest that images are best understood to be, by definition, a form of inner, mental or neural representation in the case of hypnagogic and hypnapompic imagery, it is not representational at all. Others reject the view that the image experience may be identical with (or directly caused by) any such representation in the mind or the brain, but do not take account of the non-representational forms of imagery.

In 2010 IBM applied for a patent on how to extract mental images of human faces from the human brain. It uses a feedback loop based on brain measurements of the fusiform face area in the brain which activates proportionate with degree of facial recognition.

Sound art is a diverse group of art practices that considers wide notions of sound, listening and hearing as its predominant focus. There are often distinct relationships forged between the visual and aural domains of art and perception by sound artists.

Like many genres of contemporary art, sound art is interdisciplinary in nature, or takes on hybrid forms. Sound art often engages with the subjects of acoustics, psychoacoustics, electronics, noise music, audio media and technology (both analog and digital), found or environmental sound, explorations of the human body, sculpture, film or video and an ever-expanding set of subjects that are part of the current discourse of contemporary art.

From the Western art historical tradition early examples include Luigi Russolo's Intonarumori or noise intoners, and subsequent experiments by Dadaists, Surrealists, the Situationist International, and in Fluxus happenings. Because of the diversity of sound art, there is often debate about whether sound art falls within the domain of either the visual art or experimental music categories, or both. Other artistic lineages from which sound art emerges are conceptual art, minimalism, site-specific art, sound poetry, spoken word, avant-garde poetry, and experimental theatre.

Scottish artist Susan Philipsz's 2010 British Turner Prize win for her piece Lowlands (overlapping recordings of the artist singing an ancient Scottish lament in three different versions, played back over a loudspeaker system, without any visual component) was seen as an important boost for this relatively new genre (it was the first time a work of sound art won this prestigious prize), and, in winning an art prize, again highlighted the genre's blurred boundaries with other, more visual art forms. In the same year, British artist Haroon Mirza won the Northern Art Prize for his sculptural installation that bought together video, sculptural assemblages and works from Leeds Art Gallery collection to compose a piece of music.

Chapter 8

Other Image File Formats of the Raster Type

Other image file formats of raster type include:

JPEG XR : (abbr. for JPEG extended range) is a still-image compression standard and file format for continuous tone photographic images, based on technology originally developed and patented by Microsoft under the name HD Photo (formerly Windows Media Photo). It supports both lossy and lossless compression, and is the preferred image format for Ecma-388 Open XML Paper Specification documents.

Support for the format is available in Adobe Flash Player 11.0, Adobe AIR 3.0, Sumatra PDF 2.1, Windows Imaging Component, .NET Framework 3.0, Windows Vista, Windows 7, Windows 8, Internet Explorer 9, Internet Explorer 10.[citation needed] As of June 2013, there are still no cameras that shoot photos in the JPEG XR (.JXR) format.

TGA (TARGA) True vision TGA, often referred to as TARGA, is a raster graphics file format created by True vision Inc. (now part of Avid Technology). It was the native format of TARGA and VISTA boards, which were the first graphic cards for IBM-compatible PCs to support Highcolor/truecolor display. This family of graphic cards was intended for professional computer image synthesis and video editing with PCs; for this reason, usual resolutions of TGA image files match those of the NTSC and PAL video formats.

TARGA is an acronym for Truevision Advanced Raster Graphics Adapter; TGA is an initialism for Truevision Graphics Adapter.

TGA files commonly have the extension ".tga" on PC DOS/Windows systems and Mac OS X (older Macintosh systems use the "TPIC" type code). The format can store image data with 8, 15, 16, 24, or 32 bits of precision per pixel – the maximum 24 bits of RGB and an extra 8-bit alpha channel. Color data can be color-mapped, or in direct color or truecolor format. Image data may be stored raw, or optionally, a lossless RLE compression similar to PackBits can be employed. This type of compression performs poorly for typical photographic images, but works acceptably well for simpler images, such as icons, cartoons and line drawings.

ILBM (IFF-style format for up to 32 bit in planar representation, plus optional 64 bit extensions

DEEP (IFF-style format used by TV Paint)

IMG (Graphical Environment Manager image file; planar, run-length encoded)

PCX (Personal Computer eXchange)

ECW (Enhanced Compression Wavelet)

IMG (ERDAS IMAGINE Image)

SID (multiresolution seamless image database, MrSID)

CD5 (Chasys Draw Image)

FITS (Flexible Image Transport System)

PGF (Progressive Graphics File)

XCF (eXperimental Computing Facility format, native GIMP format)

PSD (Adobe PhotoShop Document)

PSP (Corel Paint Shop Pro)

VICAR file format (NASA/JPL image transport format)

Vector formats: As opposed to the raster image formats above (where the data describes the characteristics of each individual pixel), vector image formats contain a geometric description which can be rendered smoothly at any desired display size.

At some point, all vector graphics must be rasterized in order to be displayed on digital monitors. However, vector images can be displayed with analog CRT technology such as that used in some electronic test equipment, medical monitors, radar displays, laser shows and early video games. Plotters are printers that use vector data rather than pixel data to draw graphics.

CGM: (Computer Graphics Metafile) is a file format for 2D vector graphics, raster graphics, and text, and is defined by ISO/IEC 8632. All graphical elements can be specified in a textual source file that can be compiled into a binary file or one of two text representations. CGM provides a means of graphics data interchange for computer representation of 2D graphical information independent from any particular application, system, platform, or device. It has been adopted to some extent in the areas of technical illustration and professional design, but has largely been superseded by formats such as SVG and DXF.

Gerber File Format (RS-274X): The Gerber Format (aka Extended Gerber, RS-274X) was developed by Gerber Systems Corp., now Ucamco. This is a 2D bi-level image description format. It is the de facto standard format used by printed circuit board or PCB software. It is also widely used in other industries requiring high-precision 2D bi-level images.

SVG: (Scalable Vector Graphics) is an open standard created and developed by the World Wide Web Consortium to address the need (and attempts of several corporations) for a versatile, scriptable and all-purpose vector format for the web and otherwise. The SVG format does not have a compression scheme of its own, but due to the textual nature of XML, an SVG graphic can be compressed using a program such as gzip. Because of its scripting potential, SVG is a key component in web applications: interactive web pages that look and act like applications.

Other 2D vector formats

AI (Adobe Illustrator)

CDR (CorelDRAW)

DrawingML

GEM metafiles (interpreted and written by the Graphical Environment Manager VDI subsystem)

Graphics Layout Engine

HPGL, introduced on Hewlett-Packard plotters, but generalized into a printer language

HVIF (Haiku Vector Icon Format)

MathML

MetaPost

Myv vector format

NAPLPS (North American Presentation Layer Protocol Syntax)

ODG (OpenDocument Graphics)

!DRAW, a native vector graphic format (in several backward compatible versions) for the RISC-OS computer system begun by Acorn in the mid-1980s and still present on that platform today

POV-Ray markup language

PPT (Microsoft PowerPoint)

Precision Graphics Markup Language, a W3C submission that was not adopted as a recommendation.

PSTricks and PGF/TikZ are languages for creating graphics in TeX documents.

ReGIS, used by DEC computer terminals

Remote imaging protocol

VML (Vector Markup Language)

WMF / EMF (Windows Metafile / Enhanced Metafile)

Xar format used in vector applications from Xara

XPS (XML Paper Specification)

3D vector formats

AMF - Additive Manufacturing File Format

Asymptote - A language that lifts TeX to 3D.

.blend – Blender,COLLADA,dwf, dwg, dxf,eDrawings,HSF,IGES,IMML - Immersive Media Markup ,Language, IPA, JT, PRC, STEP, SKP, STL - A stereolithography format.,U3D - Universal 3D file format, VRML - Virtual Reality Modeling Language,XAML,XGL,XVL,xVRML,X3D,3D,3DF,3DM,3ds - Autodesk 3D Studio,3DXML,X3D - Vector format used in 3D applications from Xara,

Compound formats

These are formats containing both pixel and vector data, possible other data, e.g. the interactive features of PDF.

EPS (Encapsulated PostScript) : EPS is a DSC-conforming PostScript document with additional restrictions which is intended to be usable as a graphics file format. In other words, EPS files are more-or-less self-contained, reasonably predictable PostScript documents that describe an image or drawing and can be placed within another PostScript document. Simply, an EPS file is a PostScript program, saved as a single file that includes a low-resolution preview "encapsulated" inside of it, allowing some programs to display a preview on the screen.

At minimum, an EPS file contains a Bounding Box DSC comment, describing the rectangle containing the image described by the EPS file. Applications can use this information to lay out the page, even if they are unable to directly render the PostScript inside.

EPS: together with DSC's Open Structuring Conventions, form the basis of early versions of the Adobe Illustrator Artwork file format.

PDF (Portable Document Format): Portable Document Format (PDF) is a file format used to represent documents in a manner independent of application software, hardware, and operating system. Each PDF file encapsulates a complete description of a fixed-layout flat document, including the text, fonts, graphics, and other information needed to display it. In 1991, Adobe Systems co-founder John Warnock outlined a system called "Camelot" that evolved into PDF.

While Adobe Systems made the PDF specification available free of charge in 1993, PDF remained a proprietary format, controlled by Adobe, until it was officially released as an open standard on July 1, 2008, and published by the International Organization for Standardization as ISO 32000-1:2008.In 2008, Adobe published a Public Patent License to ISO 32000-1 granting royalty-free rights for all patents owned by Adobe that are necessary to make, use, sell and distribute PDF compliant implementations. However, there are still some technologies used in PDF files that are defined only by Adobe and remain proprietary (e.g. Adobe XML Forms Architecture, Adobe JavaScript

PostScript, a page description language with strong graphics capabilities

PICT (Classic Macintosh QuickDraw file)

SWF (Shockwave Flash)

XAML User interface language using vector graphics for images.

Stereo formats

MPO: The Multi Picture Object (.mpo) format consists of multiple JPEG images (Camera & Imaging Products Association) (CIPA).

PNS: The PNG Stereo (.pns) format consists of a side-by-side image based on PNG (Portable Network Graphics).

JPS: The JPEG Stereo (.jps) format consists of a side-by-side image format based on JPEG.

Chapter 9

Image File Formats

Image file formats are standardized means of organizing and storing digital images. Image files are composed of digital data in one of these formats that can be rasterized for use on a computer display or printer. An image file format may store data in uncompressed, compressed, or vector formats. Once rasterized, an image becomes a grid of pixels, each of which has a number of bits to designate its color equal to the color depth of the device displaying it.

Image file sizes: Generally speaking, in raster images, Image file size is positively correlated to the number of pixels in an image and the color depth, or bits per pixel, of the image. Images can be compressed in various ways, however. Compression uses an algorithm that stores an exact representation or an approximation of the original image in a smaller number of bytes that can be expanded back to its uncompressed form with a corresponding decompression algorithm. Considering different compressions, it is common for two images of the same number of pixels and color depth to have a very different compressed file size. Considering exactly the same compression, number of pixels, and color depth for two images, different graphical complexity of the original images may also result in very different file sizes after compression due to the nature of compression algorithms. With some compression formats, images that are less complex may result in smaller compressed file sizes. This characteristic sometimes results in a smaller file size for some lossless formats than lossy formats. For example, graphically simple images (i.e. images with large continuous regions like line art or animation sequences) may be losslessly compressed into a GIF or PNG format and result in a smaller file size than a lossy JPEG format.

Vector images, unlike raster images, can be any dimension independent of file size. File size increases only with the addition of more vectors.

Algorithms : In mathematics and computer science, an algorithm is a step-by-step procedure for calculations. Algorithms are used for calculation, data processing, and automated reasoning.

An algorithm is an effective method expressed as a finite list of well-defined instructions for calculating a function. Starting from an initial state and initial input the instructions describe a computation that, when executed, proceeds through a finite number of well-defined successive states, eventually producing "output" and terminating at a final ending state. The transition from one state to the next is not necessarily deterministic; some algorithms, known as randomized algorithms, incorporate random input.

Though al-Khwārizmī's algorism referred to the rules of performing arithmetic using Hindu-Arabic numerals and the systematic solution of linear and quadratic equations, a partial formalization of what would become the modern algorithm began with attempts to solve the Entscheidungsproblem (the "decision problem") posed by David Hilbert in 1928. Subsequent formalizations were framed as attempts to define "effective calculability or "effective method" those formalizations included the Gödel–Herbrand–Kleene recursive functions of 1930, 1934 and 1935, Alonzo Church's lambda calculus of 1936, Emil Post's "Formulation 1" of 1936, and Alan Turing's Turing machines of 1936–7 and 1939. Giving a formal definition of algorithms, corresponding to the intuitive notion, remains a challenging problem.

Image file compression: There are two types of image file compression algorithms: lossless and lossy.

Lossless compression algorithms reduce file size while preserving a perfect copy of the original uncompressed image. Lossless compression generally, but not always, results in larger files than lossy compression. Lossless compression should be used to avoid accumulating stages of re-compression when editing images.

Lossy compression algorithms preserve a representation of the original uncompressed image that may appear to be a perfect copy, but it is not a perfect copy. Often lossy compression is able to achieve smaller file sizes than lossless compression. Most lossy compression algorithms allow for variable compression that trades image quality for file size.

Major graphic file formats: Including proprietary types, there are hundreds of image file types. The PNG, JPEG, and GIF formats are most often used to display images on the Internet. These graphic formats are listed and briefly described below, separated into the two main families of graphics: raster and vector.

In addition to straight image formats, Metafile formats are portable formats which can include both raster and vector information. Examples are application-independent formats such as WMF and EMF. The metafile format is an intermediate format. Most Windows applications open metafiles and then save them in their own native format. Page description language refers to formats used to describe the layout of a printed page containing text, objects and images. Examples are PostScript, PDF and PCL.

Raster formats:-

JPEG/JFIF:JPEG (Joint Photographic Experts Group) is a lossy compression method; JPEG-compressed images are usually stored in the JFIF (JPEG File Interchange Format) file format. The JPEG/JFIF filename extension is JPG or JPEG. Nearly every digital camera can save images in the JPEG/JFIF format, which supports 8-bit grayscale images and 24-bit color images (8 bits each for red, green, and blue). JPEG applies lossy compression to images, which can result in a significant reduction of the file size. The amount of compression can be specified, and the amount of compression affects the visual quality of the result. When not too great, the compression does not noticeably detract from the image's quality, but JPEG files suffer generational degradation when repeatedly edited and saved. (JPEG also provides lossless image storage, but the lossless version is not widely supported.)

JPEG 2000: JPEG 2000 is a compression standard enabling both lossless and lossy storage. The compression methods used are different from the ones in standard JFIF/JPEG; they improve quality and compression ratios, but also require more computational power to process. JPEG 2000 also adds features that are missing in JPEG. It is not nearly as common as JPEG, but it is used currently in professional movie editing and distribution (some digital cinemas, for example, use JPEG 2000 for individual movie frames).

Exif: The Exif (Exchangeable image file format) format is a file standard similar to the JFIF format with TIFF extensions; it is incorporated in the JPEG-writing software used in most cameras. Its purpose is to record and to standardize the exchange of images with image metadata between digital cameras and editing and viewing software. The metadata are recorded for individual images and include such things as camera settings, time and date, shutter speed, exposure, image size, compression, name of camera, color information. When images are viewed or edited by image editing software, all of this image information can be displayed.

The actual Exif metadata as such may be carried within different host formats, e.g. TIFF, JFIF (JPEG) or PNG. IFF-META is another example.

TIFF: The TIFF (Tagged Image File Format) format is a flexible format that normally saves 8 bits or 16 bits per color (red, green, blue) for 24-bit and 48-bit totals, respectively, usually using either the TIFF or TIF filename extension. TIFF's flexibility can be both an advantage and disadvantage, since a reader that reads every type of TIFF file does not exist[citation needed]. TIFFs can be lossy and lossless; some offer relatively good lossless compression for bi-level (black&white) images. Some digital cameras can save in TIFF format, using the LZW compression algorithm for lossless storage. TIFF image format is not widely supported by web browsers. TIFF remains widely accepted as a photograph file standard in the printing business. TIFF can handle device-specific color spaces, such as the CMYK defined by a particular set of printing press inks. OCR (Optical Character Recognition) software packages commonly generate some (often monochromatic) form of TIFF image for scanned text pages.

RAW:RAW refers to raw image formats that are available on some digital cameras, rather than to a specific format. These formats usually use a lossless or nearly lossless compression, and produce file sizes smaller than the TIFF formats. Although there is a standard raw image format, (ISO 12234-2, TIFF/EP), the raw formats used by most cameras are not standardized or documented, and differ among camera manufacturers.

Most camera manufacturers have their own software for decoding or developing their raw file format, but there are also many third-party raw file converter applications available that accept raw files from most digital cameras. Some graphic programs and image editors may not accept some or all raw file formats, and some older ones have been effectively orphaned already.

Adobe's Digital Negative (DNG) specification is an attempt at standardizing a raw image format to be used by cameras, or for archival storage of image data converted from undocumented raw image formats, and is used by several niche and minority camera manufacturers including Pentax, Leica, and Samsung. The raw image formats of more than 230 camera models, including those from manufacturers with the largest market shares such as Canon, Nikon, Phase One, Sony, and Olympus, can be converted to DNG.[1] DNG was based on ISO 12234-2, TIFF/EP, and ISO's revision of TIFF/EP is reported to be adding Adobe's modifications and developments made for DNG into profile 2 of the new version of the standard.

As far as videocameras are concerned, ARRI's Arriflex D-20 and D-21 cameras provide raw 3K-resolution sensor data with Bayer pattern as still images (one per frame) in a proprietary format (.ari file extension). Red Digital Cinema Camera Company, with its Mysterium sensor family of still and video cameras, uses its proprietary raw format called REDCODE (.R3D extension), which stores still as well as audio+video information in one lossy-compressed file.

GIF:GIF (Graphics Interchange Format) is limited to an 8-bit palette, or 256 colors. This makes the GIF format suitable for storing graphics with relatively few colors such as simple diagrams, shapes, logos and cartoon style images. The GIF format supports animation and is still widely used to provide image animation effects. It also uses a lossless compression that is more effective when large areas have a single color, and ineffective for detailed images or dithered images.

BMP: The BMP file format (Windows bitmap) handles graphics files within the Microsoft Windows OS. Typically, BMP files are uncompressed, hence they are large; the advantage is their simplicity and wide acceptance in Windows programs.

PNG: The PNG (Portable Network Graphics) file format was created as the free, open-source successor to GIF. The PNG file format supports 8 bit paletted images (with optional transparency for all palette colors) and 24 bit truecolor (16 million colors) or 48 bit truecolor with and without alpha channel - while GIF supports only 256 colors and a single transparent color. Compared to JPEG, PNG excels when the image has large, uniformly colored areas. Thus lossless PNG format is best suited for pictures still under edition - and the lossy formats, like JPEG, are best for the final distribution of photographic images, because in this case JPG files are usually smaller than PNG files. The Adam7-interlacing allows an early preview, even when only a small percentage of the image data has been transmitted.

PNG provides a patent-free replacement for GIF and can also replace many common uses of TIFF. Indexed-color, grayscale, and truecolor images are supported, plus an optional alpha channel.

PNG is designed to work well in online viewing applications like web browsers so it is fully streamable with a progressive display option. PNG is robust, providing both full file integrity checking and simple detection of common transmission errors. Also, PNG can store gamma and chromaticity data for improved color matching on heterogeneous platforms.

Some programs do not handle PNG gamma correctly, which can cause the images to be saved or displayed darker than they should be.

Animated formats derived from PNG are MNG and APNG. The latter is supported by Mozilla Firefox and Opera and is backwards compatible with PNG.

PPM, PGM, PBM, PNM and PFM: Netpbm format is a family including the portable pixmap file format (PPM), the portable graymap file format (PGM) and the portable bitmap file format (PBM). These are either pure ASCII files or raw binary files with an ASCII header that provide very basic functionality and serve as a lowest common denominator for converting pixmap, graymap, or bitmap files between different platforms. Several applications refer to them collectively as PNM or PAM format (Portable Any Map). PFM was invented later in order to carry floating-point-based pixel information (as used in HDR).

PAM: A late addition to the PNM family is the PAM format (Portable Arbitrary Format).

WEBP:WebP is a new open image format that uses both lossless and lossy compression. It was designed by Google to reduce image file size to speed up web page loading: its principal purpose is to supersede JPEG as the primary format for photographs on the web. WebP now supports animated images and alpha channel (transparency) in lossy images. WebP is based on VP8's intra-frame coding and uses a container based on RIFF.

HDR Raster formats: Most typical raster formats cannot store HDR data (32 bit floating point values per pixel component), which is why some relatively old or complex formats are still predominant here, and worth mentioning separately. Newer alternatives are showing up, though.

RGBE (Radiance HDR): The classical representation format for HDR images, originating from Radiance **and also supported by Adobe Photoshop.**

IFF-RGFX: IFF-RGFX the native format of SView5 provides a straightforward IFF-style representation of any kind of image data ranging from 1-128 bit (LDR and HDR), including common meta data like ICC profiles, XMP, IPTC or EXIF

Chapter 10

Satellite Digital Imaging System & Exposing to the Light

The Satellite Digital Imaging System (SDIS) is a simple system composed of Commercial Off-the-Shelf (COTS) hardware and custom integration software, which allows the operator to transmit digital photos from an aircraft in flight to a ground station. It is currently used by the United States Civil Air Patrol (CAP) for domestic search and rescue operations and commercial photography.

Commercial off-the-shelf: In the United States, Commercial Off-The-Shelf (COTS) is a Federal Acquisition Regulation (FAR) term for goods available in the commercial marketplace that can be bought and used under government contract. For example consumer goods and construction materials may qualify but bulk cargo does not.

COTS purchases are alternatives to in-house developments or one-off government-funded developments. COTS typically requires configuration that is tailored for specific uses. The use of COTS has been mandated across many government and business programs, as such products may offer significant savings in procurement, development, and maintenance.

Motivations for using COTS components include hopes for reduction of overall system-development and costs (as components can be bought or licensed instead of being developed from scratch) and reduced long-term maintenance costs. In the 1990s many regarded COTS as extremely effective in reducing cost and time In software development. COTS software came with many not-so-obvious tradeoffs—initial cost and development time can be reduced, but often with an increase in software component-integration work and also a dependency on the vendor, security issues and incompatibilities from future changes.

Search and rescue (SAR or S&R) is the search for and provision of aid to people who are in distress or imminent danger.

The general field of search and rescue includes many specialty sub-fields, typically determined by the type of terrain the search is conducted over. These include mountain rescue; ground search and rescue, including the use of search and rescue dogs; urban search and rescue in cities; combat search and rescue on the battlefield and air-sea rescue over water.

Components

Nikon D100 digital SLR camera.

Panasonic Toughbook laptop computer with SDIS software installed.

Satellite telephone.

The SDIS consists essentially of connecting these three devices to one another. No hardware is physically installed in the aircraft.

Operation: Prior to takeoff, the operator connects the laptop to the Web Mission Information Reporting System (WMIRS) and obtains a mission identifier. During flight, photos are downloaded to the laptop computer and e-mailed to the customer or CAP base using the satellite phone. Images are also captured to a memory card in the digital camera, and may be edited or uploaded to the WMIRS after landing.

The Satellite Digital Imaging System (SDIS) was demonstrated successfully in the search and recovery efforts following hurricanes Katrina and Rita in 2005.

Advantages / Disadvantages[edit]

Advantages: Near Real-Time, Low Cost, Multi-facet Use

Disadvantages: Unreliable (If high cloud-cover is present satellite acquisition is difficult), Slow Upload (Due to Sat. Feed)

Exposing to the right: In digital photography, exposing to the right (ETTR) is the technique of increasing the exposure of an image in order to collect the maximum amount of light and thus get the optimum performance out of the digital image sensor. The name derives from the resulting image histogram which, according to this technique, should be placed close to the right of its display. Advantages include greater tonal range in dark areas, greater signal-to-noise ratio (SNR), fuller use of the colour gamut and greater latitude during post-production.

ETTR images appear to be overexposed when taken and must be correctly processed (normalized) to produce a photograph as envisaged, therefore care must be taken to avoid clipping within any colour channel, other than acceptable areas such as specular highlights.

The principle is also applied in film photography in order to maximize the negative's latitude and density and achieve richer blacks when the image is printed slightly down.

Exposure (photography): In photography, exposure is the quantity of light reaching a photographic film, as determined by shutter speed and lens aperture. In digital photography "film" is substituted with "sensor". Exposure is measured in lux seconds, and can be computed from exposure value (EV) and scene luminance in a specified region.

In photographic jargon, an exposure generally refers to a single shutter cycle. For example: a long exposure refers to a single, protracted shutter cycle to capture enough low-intensity light, whereas a multiple exposure involves a series of relatively brief shutter cycles; effectively layering a series of photographs in one image. For the same film speed, the accumulated photometric exposure (Hv) should be similar in both cases.

Signal-to-noise ratio (imaging): The signal-to-noise ratio (SNR) is used in imaging as a physical measure of the sensitivity of a (digital or film) imaging system. Industry standards measure SNR in decibels (dB) of power and therefore apply the 20 log rule to the "pure" SNR ratio (a ratio of 1:1 yields 0 decibels, for instance). In turn, yielding the "sensitivity." Industry standards measure and define sensitivity in terms of the ISO film speed equivalent; SNR:32.04 dB = excellent image quality and SNR:20 dB = acceptable image quality.

Gamut: In color reproduction, including computer graphics and photography, the gamut, or color gamut /ˈɡæmət/, is a certain complete subset of colors. The most common usage refers to the subset of colors which can be accurately represented in a given circumstance, such as within a given color space or by a certain output device. Another sense, less frequently used but not less correct, refers to the complete set of colors found within an image at a given time. In this context, digitizing a photograph, converting a digitized image to a different color space, or outputting it to a given medium using a certain output device generally alters its gamut, in the sense that some of the colors in the original are lost in the process.

Latitude: Latitude is the degree by which one can over, or under expose an image, and still recover an acceptable level of quality from an exposure. Typically negative film has a better ability to record a range of brightness than slide/transparency film or digital. Digital should be considered to be the reverse of print film, with a good latitude in the shadow range, and a narrow one in the highlight area; in contrast to film's large highlight latitude, and narrow shadow latitude. Slide/Transparency film has a narrow latitude in both highlight and shadow areas, requiring greater exposure accuracy.

Negative film's latitude increases somewhat with high ISO material, in contrast digital tends to narrow on latitude with high ISO settings.

Post-production is part of filmmaking, video production and photography process. It occurs in the making of motion pictures, television programs, radio programs, advertising, audio recordings, photography, and digital art. It is a term for all stages of production occurring after the actual end of shooting and/or recording the completed work.

Background: ETTR is founded upon the linearity of CCD and CMOS sensors, whereby the electric charge accumulated by each subpixel is proportional to the amount of light it is exposed to (plus electronic noise). Although a camera may have a dynamic range of 5 or more stops, when image data is recorded digitally the highest (brightest) stop uses fully half of the discrete tonal values. This is because a difference of 1 stop represents a doubling or halving of exposure. The next highest stop uses half of the remaining values, the next uses half of what is left and so on, such that the lowest stop uses only a small fraction of the tonal values available. This may result in a loss of tonal detail in the dark areas of a photograph and posterization during post-production. By deliberately exposing to the right and then stopping down afterwards (during processing) the maximum amount of information is retained.

The technique was first described in 2003 by Michael Reichmann on his website, after purportedly having a discussion with software engineer Thomas Knoll, the original author of Adobe Photoshop and developer of the Camera Raw plug-in.

Linearity: In mathematics, a linear map or linear function f(x) is a function which satisfies the following two properties:

Additivity (also called the superposition property): $f(x + y) = f(x) + f(y)$.

Homogeneity of degree 1: $f(\alpha x) = \alpha f(x)$ for all α.

It can be shown that additivity implies the homogeneity in all cases where α is rational; this is done by proving the case where α is a natural number by mathematical induction and then extending the result to arbitrary rational numbers. If f is assumed to be continuous as well then this can be extended to show that homogeneity for α any real number, using the fact that rationals form a dense subset of the reals.

In this definition, x is not necessarily a real number, but can in general be a member of any vector space. A more specific definition of linear function, not coinciding with the definition of linear map, is used in elementary mathematics.

The concept of linearity can be extended to linear operators. Important examples of linear operators include the derivative considered as a differential operator, and many constructed from it, such as del and the Laplacian. When a differential equation can be expressed in linear form, it is particularly easy to solve by breaking the equation up into smaller pieces, solving each of those pieces, and summing the solutions.

Linear algebra is the branch of mathematics concerned with the study of vectors, vector spaces (also called linear spaces), linear transformations (also called linear maps), and systems of linear equations.

The word linear comes from the Latin word linearis, which means pertaining to or resembling a line. For a description of linear and nonlinear equations, see linear equation. Nonlinear equations and functions are of interest to physicists and mathematicians because they can be used to represent many natural phenomena, including chaos.

Subpixels: Many display and image-acquisition systems are, for various reasons, not capable of displaying or sensing the different color channels at the same site. Therefore, the pixel grid is divided into single-color regions that contribute to the displayed or sensed color when viewed at a distance. In some displays, such as LCD, LED, and plasma displays, these single-color regions are separately addressable elements, which have come to be known as subpixels. For example, LCDs typically divide each pixel horizontally into three subpixels. When the square pixel is divided into three subpixels, each subpixel is necessarily rectangular. In the display industry terminology, subpixels are often referred to as pixels, as they are the basic addressable elements in a viewpoint of hardware, and they call pixel circuits rather than subpixel circuits.

Most digital camera image sensors use single-color sensor regions, for example using the Bayer filter pattern, and in the camera industry these are known as pixels just like in the display industry, not subpixels.

For systems with subpixels, two different approaches can be taken:

The subpixels can be ignored, with full-color pixels being treated as the smallest addressable imaging element; or

The subpixels can be included in rendering calculations, which requires more analysis and processing time, but can produce apparently superior images in some cases.

This latter approach, referred to as subpixel rendering, uses knowledge of pixel geometry to manipulate the three colored sub pixels separately, producing a slight increase in the apparent resolution of color displays. While CRT displays use red-green-blue-masked phosphor areas, dictated by a mesh grid called the shadow mask, it would require a difficult calibration step to be aligned with the displayed pixel raster, and so CRTs do not currently use subpixel rendering.

The concept of subpixels is related to samples.

Limitations: This technique is only relevant for use when shooting in a raw image format then processing in a raw converter before exporting the file to a raster graphics editor. If the technique is used with JPEG files (the default on most consumer cameras) it will not work as intended and may result in overexposed pictures for low-contrast scenes and underexposure for high-contrast scenes. Exposing to the right by increasing the ISO setting (in digital camera systems) will not work as intended and may result in increased noise. The practical usefulness of this technique in many circumstances, especially in conjunction with modern cameras and modern photo editing software, has been disputed.

Chapter 11

Photographic film

Photographic film is a strip or sheet of transparent plastic film base coated on one side with a gelatin emulsion containing microscopically small light-sensitive silver halide crystals. The sizes and other characteristics of the crystals determine the sensitivity, contrast and resolution of the film.

The emulsion will gradually darken if left exposed to light, but the process is too slow and incomplete to be of any practical use. Instead, a very short exposure to the image formed by a camera lens is used to produce only a very slight chemical change, proportional to the amount of light absorbed by each crystal. This creates an invisible latent image in the emulsion which can be chemically developed into a fully visible photograph.

In addition to visible light, all films are sensitive to X-rays and high-energy particles. Many are at least slightly sensitive to invisible ultraviolet (UV) light. Some special-purpose films are sensitive into the infrared (IR) region of the spectrum.

In black-and-white photographic film there is usually one layer of silver salts. When the exposed grains are developed, the silver salts are converted to metallic silver, which blocks light and appears as the black part of the film negative.

Color film uses at least three layers. Dyes, which adsorb to the surface of the silver salts, make the crystals sensitive to different colors. Typically the blue-sensitive layer is on top, followed by the green and red layers. During development, the exposed silver salts are converted to metallic silver, just as with black-and-white film. But in a color film, the by-products of the development reaction simultaneously combine with chemicals known as color couplers that are included either in the film itself or in the developer solution to form colored dyes. Because the by-products are created in direct proportion to the amount of exposure and development, the dye clouds formed are also in proportion to the exposure and development. Following development, the silver is converted back to silver salts in the bleach step. It is removed from the film in the fix step. This leaves behind only the formed color dyes, which combine to make up the colored visible image.

Newer color films, like Kodacolor II, have as many as 12 emulsion layers,[citation needed] with upwards of 20 different chemicals in each layer.

Due to film photography's long history of widespread use, there are now around one trillion pictures on photographic film or photographic paper in the world, enough to cover an area of around ten thousand square kilometres (4000 square miles), about half the size of Wales.

Film basics: There are several types of photographic film, including:

Print film, when developed, yields transparent negatives with the light and dark areas and colors (if color film is used) inverted to their opposites. This type of film is designed to be printed onto photographic paper, usually by means of an enlarger but in some cases by contact printing. The paper is then itself developed. The second inversion that results restores light, shade and color to their normal appearance. Color negatives incorporate an orange color correction mask that compensates for unwanted dye absorptions and improves color accuracy in the prints. Although color processing is more complex and temperature-sensitive than black-and-white processing, the wide availability of commercial color processing and scarcity of service for black-and-white prompted the design of some black-and-white films which are processed in exactly the same way as standard color film.

Color reversal film produces positive transparencies, also known as diapositives, which are sometimes inspected with the aid of a magnifying loupe and a lightbox. If mounted in small metal, plastic or cardboard frames for use in a slide projector or slide viewer they are commonly called slides. Reversal film is often marketed as "slide film". Large-format color reversal sheet film is used by some professional photographers, typically to originate very-high-resolution imagery for digital scanning into color separations for mass photomechanical reproduction. Photographic prints can be produced from reversal film transparencies, but this is usually more expensive and complex than printing from a negative.

Black-and-white reversal film exists but is very uncommon. Conventional black-and-white negative film can be reversal-processed to produce black-and-white slides, as by dr5 Chrome. Although kits of chemicals for black-and-white reversal processing may no longer be available to amateur darkroom enthusiasts, an acid bleaching solution, the only unusual component which is essential, is easily prepared from scratch. Black-and-white transparencies may also be produced by printing negatives onto special positive print film, still available from some specialty photographic supply dealers.

In order to produce a usable image, the film needs to be exposed properly. The amount of exposure variation that a given film can tolerate while still producing an acceptable level of quality is called its exposure latitude. Color print film generally has greater exposure latitude than other types of film. Additionally, because print film must be printed to be viewed, after-the-fact corrections for imperfect exposure are possible during the printing process.

The concentration of dyes or silver salts remaining on the film after development is referred to as optical density, or simply density; the optical density is proportional to the logarithm of the optical transmission coefficient of the developed film. A dark image on the negative is of higher density than a more transparent image.

Most films are affected by the physics of silver grain activation (which sets a minimum amount of light required to expose a single grain) and by the statistics of random grain activation by photons. The film requires a minimum amount of light before it begins to expose, and then responds by progressive darkening over a wide dynamic range of exposure until all of the grains are exposed and the film achieves (after development) its maximum optical density.

Over the active dynamic range of most films, the density of the developed film is proportional to the logarithm of the total amount of light to which the film was exposed, so the transmission coefficient of the developed film is proportional to a power of the reciprocal of the brightness of the original exposure. This is due to the statistics of grain activation: as the film becomes progressively more exposed, each incident photon is less likely to impact a still-unexposed grain, yielding the logarithmic behavior. A simple, idealized statistical model yields the equation density = 1 - (1 - k) light, where light is proportional to the number of photons hitting a unit area of film, k is the probability of a single photon striking a grain (based on the size of the grains and how closely spaced they are), and density is the proportion of grains that where hit by at least one photon.

If parts of the image are exposed heavily enough to approach the maximum density possible for a print film, then they will begin losing the ability to show tonal variations in the final print. Usually those areas will be considered overexposed and will appear as featureless white on the print. Some subject matter is tolerant of very heavy exposure; for example sources of brilliant light such as a light bulb or the sun generally appear best as a featureless white on the print.

Likewise, if part of an image receives less than the beginning threshold level of exposure, which depends upon the film's sensitivity to light—or speed—the film there will have no appreciable image density, and will appear on the print as a featureless black. Some photographers use their knowledge of these limits to determine the optimum exposure for a photograph; for one example, see the Zone System. Most automatic cameras instead try to achieve a particular average density.

Film speed: Hurter and Driffield began pioneering work on the light sensitivity of photographic emulsions in 1876. Their work enabled the first quantitative measure of film speed to be devised.

Film speed describes a film's threshold sensitivity to light. The international standard for rating film speed is the ISO scale which combines both the ASA speed and the DIN speed in the format ASA/DIN. Using ISO convention film with an ASA speed of 400 would be labeled 400/27°. A fourth naming standard is GOST, developed by the Russian standards authority. See the film speed article for a table of conversions between ASA, DIN, and GOST film speeds.

Common film speeds include ISO 25, 50, 64, 100, 160, 200, 400, 800, 1600, and 3200. Consumer print films are usually in the ISO 100 to ISO 800 range. Some films, like Kodak's Technical Pan, are not ISO rated and therefore careful examination of the film's properties must be made by the photographer before exposure and development. ISO 25 film is very "slow", as it requires much more exposure to produce a usable image than "fast" ISO 800 film. Films of ISO 800 and greater are thus better suited to low-light situations and action shots (where the short exposure time limits the total light received). The benefit of slower film is that it usually has finer grain and better color rendition than fast film. Professional photographers of static subjects such as portraits or landscapes usually seek these qualities, and therefore require a tripod to stabilize the camera for a longer exposure. Photographing subjects such as rapidly moving sports or in low-light conditions, a professional will choose a faster film.

A film with a particular ISO rating can be push-processed, or "pushed", to behave like a film with a higher ISO, by developing for a longer amount of time or at a higher temperature than usual. More rarely, a film can be "pulled" to behave like a "slower" film. Pushing generally coarsens grain and increases contrast, reducing dynamic range, to the detriment of overall quality. Nevertheless, it can be a useful tradeoff in difficult shooting environments, if the alternative is no usable shot at all.

History of film : Early photography in the form of Daguerreotypes did not use film at all. The light-sensitive chemicals were formed on the surface of a silver-plated copper sheet. The alternative calotype process produced paper negatives. Beginning in the 1850s, thin glass plates coated with photographic emulsion became the standard medium. Although fragile and heavy, the glass used for photographic plates was of better optical quality than early transparent plastics and was, at first, less expensive. Plates continued to be used long after the introduction of film, and are still manufactured for scientific use.

The first flexible photographic roll film was marketed by George Eastman in 1885, but this original "film" was actually a coating on a paper base. As part of the processing, the image-bearing layer was stripped from the paper and transferred to a hardened gelatin support. The first transparent plastic roll film followed in 1889. It was made from highly flammable nitrocellulose ("celluloid"), now usually called "nitrate film".

Although cellulose acetate or "safety film" had been introduced by Kodak in 1908, at first it found only a few special applications as an alternative to the hazardous nitrate film, which had the advantages of being considerably tougher, slightly more transparent, and cheaper. The changeover was not completed for X-ray films until 1933, and although safety film was always used for 16 mm and 8 mm home movies, nitrate film remained standard for theatrical 35 mm motion pictures until it was finally discontinued in 1951.

Spectral sensitivity: Early photographic plates and films were usefully sensitive only to blue, violet and ultraviolet light. As a result, the relative tonal values in a scene registered roughly as they would appear if viewed through a piece of deep blue glass. Blue skies with interesting cloud formations photographed as a white blank. Any detail visible in masses of green foliage was due mainly to the colorless surface gloss. Bright yellows and reds appeared nearly black. Most skin tones came out unnaturally dark, and uneven or freckled complexions were exaggerated. Photographers sometimes compensated by adding in skies from separate negatives that had been exposed and processed to optimize the visibility of the clouds, by manually retouching their negatives to adjust problematic tonal values, and by heavily powdering the faces of their portrait sitters.

In 1873, Hermann Wilhelm Vogel discovered that the spectral sensitivity could be extended to green and yellow light by adding very small quantities of certain dyes to the emulsion. The instability of early sensitizing dyes and their tendency to rapidly cause fogging initially confined their use to the laboratory, but in 1883 the first commercially dye-sensitized plates appeared on the market. These early products, described as isochromatic or orthochromatic depending on the manufacturer, made possible a more accurate rendering of colored subject matter into a black-and-white image. Because they were still disproportionately sensitive to blue, the use of a yellow filter and a consequently longer exposure time were required to take full advantage of their extended sensitivity.

In 1894, the Lumière Brothers introduced their Lumière Panchromatic plate, which was made sensitive, although very unequally, to all colors including red. New and improved sensitizing dyes were developed, and in 1902 the much more evenly color-sensitive Perchromo panchromatic plate was being sold by the German manufacturer Perutz. The commercial availability of highly panchromatic black-and-white emulsions also accelerated the development of practical color photography, which requires good sensitivity to all the colors of the spectrum for the red, green and blue channels of color information to all be captured with reasonable exposure times.

However, all of these were glass-based plate products. Panchromatic emulsions on a film base were not commercially available until the 1910s and did not come into general use until much later. In part, this was because many photographers who did their own darkroom work preferred to go without the seeming luxury of sensitivity to red—a rare color in nature and uncommon even in man-made objects—rather than be forced to abandon the traditional red darkroom safelight and process their exposed film in complete darkness. Kodak's popular Verichrome black-and-white snapshot film, introduced in 1931, remained a red-insensitive orthochromatic product until 1956, when it was replaced by Verichrome Pan. Amateur darkroom enthusiasts then had to handle the undeveloped film by the sense of touch alone

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NIILM University

9, Km Milestone, NH-65, Kaithal - 136027, Haryana
Website: www.niilmuniversity.in