SECTION 6

Basic Theory and Specifications

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- Choosing the Appropriate Bit Depth and Color Space
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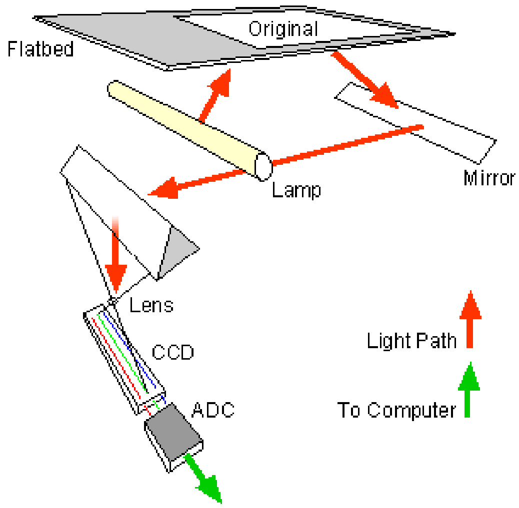
Basic Theory and Specifications

How Computers See

Basic Mechanics

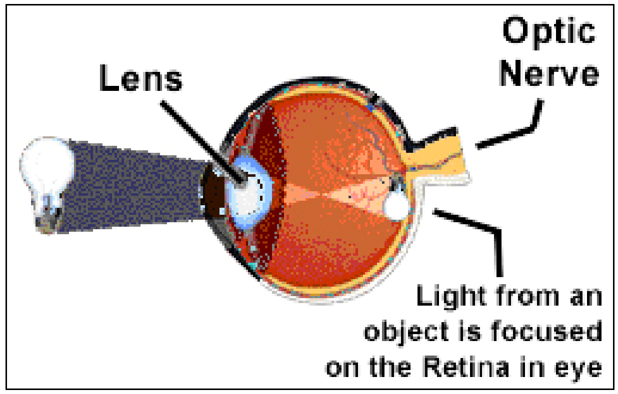
Computers, of course, are mechanical devices. And, the mechanics by which they see can be extraordinarily complex. For example, an image is captured and converted by a flatbed scanner through the following process:



Source of Image:
The Digital Image
(by the Technical Advisory Service for Images)
http://www.tasi.ac.uk/advice/creating/image.html

1. A source document is placed face-down on the platen of the flatbed scanner.
2. A lamp inside the scanner illuminates the source document.
3. Light bounces off the source document, reflected in a mirror and subsequently bounced to a prism.
4. This prism separates the image into a full spectrum of light focused on a lens.
5. The lens, in turn, directs this full spectrum light onto a charge-coupled device (CCD).
6. The CCD is an image sensor, containing a grid of light sensing devices, sometimes called *picture elements* or *pixels*, that break the image in bits of information.
7. This information, pixel by pixel, is collected by an automated data capture (ADC) device, that converts image information into numeric information.
8. This numeric information is then sent on to the computer processor unit (CPU), which makes it available to image processing software, data storage, or other processes.

This process is similar to that used by the human eye, as light reflected off of an object passes through the lens of the eye onto the retina, where it is converted into a series of electronic pulses transmitted to the brain for processing and action.



Bits Depth

```
111111000111111
111110000011111
111110000011111
111100000011111
111100010001111
111100010001111
111000111000111
111000111000111
111000111000111
110001111000011
110000000000011
110000000000001
100001111100001
100011111110001
0000111111110000
0001111111111000
```

This is an extraordinary simplification: *Computers see only numbers*. The only numbers they see are "*1*" and "*0*". Stings of *1*s & *0*s in strings may represent images, letters, numbers, etc. The numbers are called "bits" (as in "*Bit-Depth*").

Let's say that the number *0* represents the color *black* and the number *1* represents *white*. In the illustration to the left, we can clearly see a black letter A. This *bi-tonal* or black-and-white image is 15 bits wide by 16 bits high. The image of the letter A is represented by the string:

111111000111111111110000011111111110000011111111100000011111
111100010001111111100010001111111000111000111111000111000111
111000111000111110001111000011110000000000011110000000000001
100001111100001100011111110001000011111111000000011111111000

The letter A, above, is the simplest means of illustrating how bits comprise an image. This image of the letter A is black-and-white. Add shading or color, and descriptions of images become more complex. To keep it as simple as possible, let's say that *Bit Depth* is the number of *1*s and *0*s used to represent any single pixel. That string of numbers is the encoded description of a shade or color.

In digitization, generally, we speak about three levels of *Bit Depth*: 1 Bit, 8 Bit, and 24 Bit images. Sometimes, we speak about 16 Bit and 48 Bit images as well.

A **1 Bit** image is referred to as "bi-tonal" or, less precisely, as "black-and-white". The picture elements of a 1 Bit image are expressed in stings of one bit. That bit may be either one color or an alternate and, frequently either black or white.

An **8 Bit** image is referred to as "grey-scale", though an 8 Bit image may represent a very limited color spectrum as well. Most scanning equipment defaults 8 Bit imaging to grey-scale. The picture elements of an 8 Bit image are expressed in strings of eight bits, for example: 00001111. 8 Bit images allow for as many as 255 shades or colors. (N.B. Technically, 8 Bit images allow for 256 shade/color values, but one of these is reserved as a check-digit and is not used to express a shade/color value.)

An **24 Bit** image is referred to as "true color" or, less precisely, as a "color" image. The picture elements of a 24 Bit image are expressed in strings of twenty-four bits. 24 Bit images allow for as many as 16,777,216 shades or colors. You may hear digitization specialists using the short-hand "sixteen million colors".

Color in the 24 Bit image introduces an additional factor: *channels*. Because color in digital images is often a combination of three colors: Red, Green and Blue (see also: *Color, Color Space, and Color Metrics* below), the 24 bits is often divided into three 8 Bit channels, one for each of three composite colors. Most scanning equipment defaults 24 Bit imaging to color, with 8 Bits per channel.

Color, Color Space, and Color Metrics

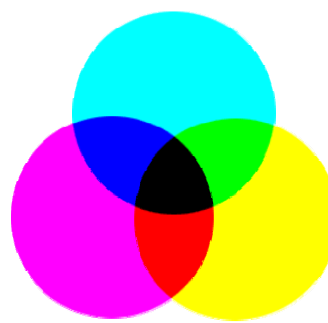
Color fidelity is fundamental to accurate reproduction of source.

Digitization, faithful to original colors, requires a basic understanding of color and how color reproduction differs from printing technology to digital technology. Fundamental to these differences is the media on which a color image is *printed*.

Calibration of equipment or, at least, understanding color metrics is also important.

Printing Technology and Color

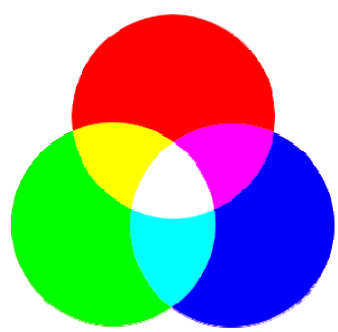
Paper is the media of printing technologies. Most paper is white. This much is obvious: white is given, and black must be created.



Most commercial printing technology employs four colors: cyan, magenta, yellow and black. Some consumer-market (i.e., *desk-top*) printers employ three colors: cyan, magenta and yellow. Combinations of these colors produce other colors. The sum of these colors produces, particularly in three-color printing, produces black.

Digital Technology and Color

Digital technologies are considerably different and in some ways the inverse of printing technologies. The screen is the media of digital technologies. Most screens are black – think of them in their *off* state. Black is given, and white must be created.



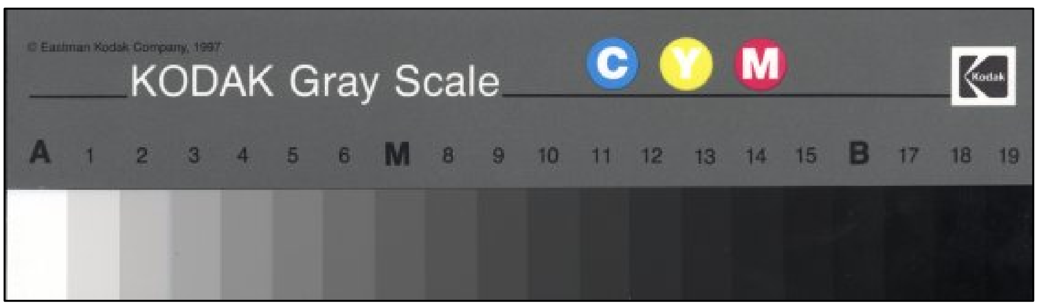
Digital technology employs three colors to do this: red, green and blue. The red, green and blue colors are referred to as *channels* (see also *Bit-Depth* above). Red, green and blue are the colors used by cathode ray tube (CRT) display systems to paint a picture on a computer monitor. Combinations of these colors produce other colors. And, the sum of these colors produces white.

Various *color-spaces* and color *profiles* are employed to control on-screen color generation. The color space most commonly used by digitization projects and required by dLOC, is a standardized Red/Green/Blue (*sRGB*) color space.

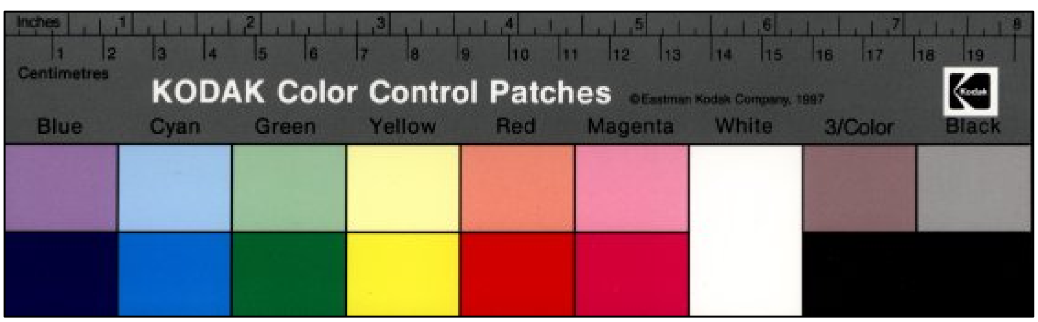
The sRGB color-space was designed to match how CRT monitors produce color. Use of the sRGB color-space ensures the delivery of images as intended to the computer screen, presuming monitor calibration (see *Adobe Gamma Correction* tool in the Image *Correction* section).

Color Metrics

Digitally reproduced colors may be measured to assess digital image quality. Three *controlled* colors – white, black and red – are measured using standard targets as seen here.



GRAY SCALE TARGET: used to measure white and black.



COLOR TARGET: used to measure white, black, and red.

Q60 Target combines both the Grey-scale and Color targets.
This target is standardized by American National Standard IT8.7/1.

The eye-dropper tool in Adobe Photoshop and other image editing software may be used to measure a color's value (i.e., to express a color numerically). The standard RGB values of *controlled* colors is expressed in the following table.

	WHITE CONTROLLED COLOR	RED CONTROLLED COLOR	BLACK CONTROLLED COLOR
RED CHANNEL	255	255	0
GREEN CHANNEL	255	0	0
BLUE CHANNEL	255	0	0

When measuring colors <u>not</u> from a standard target, color values will differ from these standard values depending upon source document characteristics. When measuring *controlled* colors from standard targets, however, values per channel (*red*, *green* or *blue*) should not be differ by more than ±10 from the numbers in the table above.

	dLOC Acceptable Color Values *per* Channel		
	WHITE	RED	BLACK
RED CHANNEL	245-255	245-255	0-10
GREEN CHANNEL	245-255	0-10	0-10
BLUE CHANNEL	245-255	0-10	0-10

dLOC recommends periodic calibration of all digitization equipment, including scanners and monitors. When purchasing scanners, select scanners bundled with calibration software. dLOC recommends simple steps to ensure the monitor's color fidelity:

- **Use Adobe Gamma Correction**
  This software comes bundled with Adobe Photoshop and Adobe Elements. Similar software is packaged with other popular image processing software.
- **Use indirect lighting in scanning and quality control areas**
  Light from windows and electrical devices influence the human eye and, in turn, have impact upon image quality assessment.
- **Surround scanning and quality control areas with neutral colors**
  Colors from the environment in which scanning and quality control take place influences the human eye and, in turn, has impact upon image quality assessment.
- **Monitor calibration software**
  This software assesses on-screen color delivery and performance. It must be purchased separately.

Choosing the Appropriate Bit Depth and Color Space

1 Bit Image

PROPRIUM
SANCTORUM.
Pars Hyemalis.

8 Bit Image

PROPRIUM
SANCTORUM.
Pars Hyemalis.

24 Bit Image

PROPRIUM
SANCTORUM.
Pars Hyemalis.

dLOC recommends that 1 Bit imaging should **not** be used. 1 Bit images, even at very high resolution (see, *Resolution* below), tend to *pixelate* text. Imperfections on the page or artifacts of age may read as *black*, obscuring text in 1 Bit images. In the 1 Bit page image above, bleed through from the text printed on the inverse page as well as artifacts of age obscure the text. Obscured text will introduce imperfections that reduce the accuracy of text conversion by optical character recognition (OCR) software.

Otherwise, dLOC recommends digitizing at the bit-depth, either 8 Bit or 24 Bit, most appropriate to the source document.

8 Bit Image

Pars Hy
DIE XXIX. NOVEMBR.
Sancti Saturnini mart.
Commemoratio.
Ad Vesperas, Antiph.
Iste sanctus pro lege Dei sui certavit usque ad mortem, & à verbis impiorum non timuit: fundatus enim erat supra firmã petram. Gloria & honore coronasti eũ Dñe. Et constituisti eum super opera ma-

24 Bit Image

Pars Hy
DIE XXIX. NOVEMBR.
Sancti Saturnini mart.
Commemoratio.
Ad Vesperas, Antiph.
Iste sanctus pro lege Dei sui certavit usque ad mortem, & à verbis impiorum non timuit: fundatus enim erat supra firmã petram. Gloria & honore coronasti eũ Dñe. Et constituisti eum super opera ma-

Which is more appropriate? The 8 Bit image captures the textual information. And, the reader of the page can make sense of the text. Need the image do more? Readers of Latin religious texts, such as that seen above, will recognize the red text as instructions to the faithful, commentary on the spoken text of a religious service, or the narrative of the priest as opposed to that of the congregation's response.

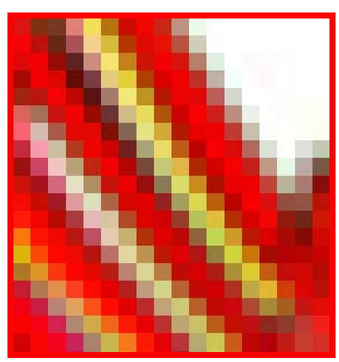
dLOC advocates a policy of preserving *meaningful* color. Meaningful color is color required to interpret the text. In the case of a newspaper with colored images, a color image accompanying an article demonstrates meaningful color, while a color advertisement may not.

It is true that "*The greater the Bit Depth the greater the size of the digital image file*". But, digitization technicians are encouraged to produce images that meet the reader's needs rather than the needs of the digitization technician to conserve space.

Resolution

The resolution of digital images is expressed in terms of pixels. A pixel is a picture element or, simply, a block of solid shade or color that, together with other picture elements comprises a digital image.

Trinidad and Tobago's Coat of Arms



Pixels in the wing of the red ibis.

(*Zoom area in black box.*)

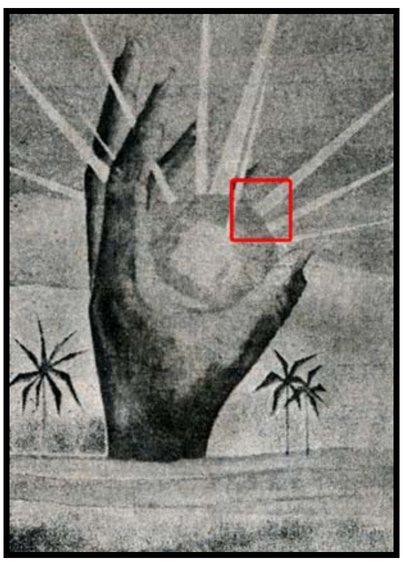
	RESOLUTION	USE FOR
OR	300 pixels per inch (ppi) 118 pixels per centimeter (ppc)	Printed text with *normal* sized fonts Oversized documents and maps Manuscripts with legible script
OR	600 pixels per inch (ppi) 236 pixels per centimeter (ppc)	Photographs and select graphic arts Printed text with *very small* fonts Manuscripts with difficult scripts

The dLOC's minimum digital resolution standard for printed text with normal sized fonts is 300 pixels per inch (ppi) or 118 pixels per centimeter (ppc). This threshold is based on both the characteristics of printed graphics and optical character recognition (OCR) tests.

300 ppi / 118 ppc

The Rationale for Printed Graphics

In general, the resolution of printed graphics does not exceed 300 dots per inch (dpi) or 118 dots per centimeter (dpc). Dots per inch/centimetre are rough equivalents of pixels per inch/centimetre; so comparison is appropriate.



Carifesta '72 logo as printed in Guyana's Sunday Post and Weekend Argosy (*Zoom area in red box.*)

Dots in grid pattern used to depict rays of light emanating from the sun.

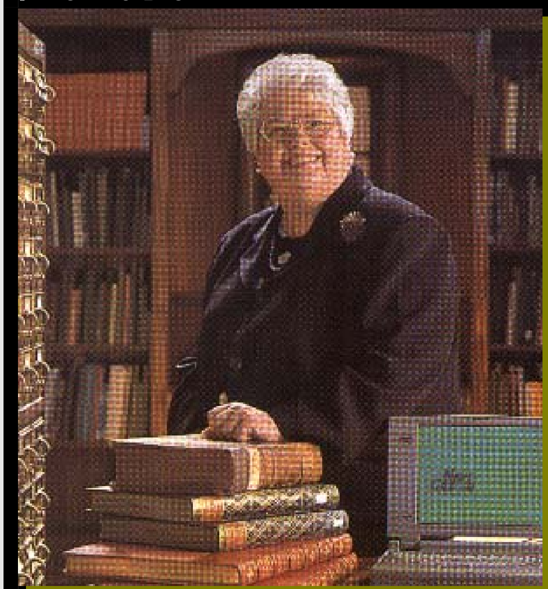
Graphics printed in newspapers, for example, often have 80 to 100 dpi (32 to 40 dpc). Most graphics in magazines are printed with 120 dpi (48 dpc) print resolution while graphics in high-end magazines and on post-cards are printed with 300 dpi (118 dpc) print resolution.

Digitization of printed graphics at resolution greater than 300 ppi (118 ppc) would be excessive.

A Brief Diversion

Image processing software supports *blur* methods (e.g., *Gaussian Blur*) that can trick the human eye into perceiving an image as a photograph (i.e., *continuous tone* image) rather than as a series of dots. Consider, for example, these images:

IMAGE AS DIGITIZED



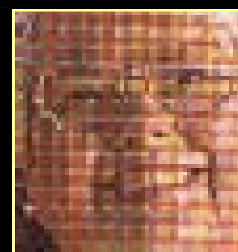
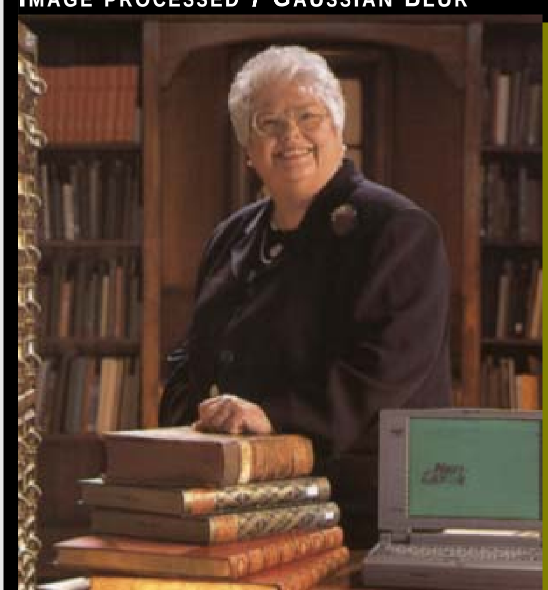


IMAGE PROCESSED / GAUSSIAN BLUR

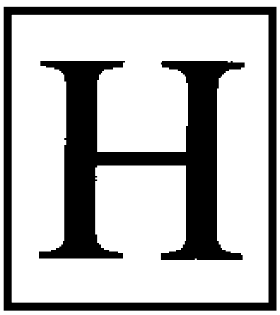


dLOC recommends that blur **not** be used. We want to archive images faithful to the original. Besides, when images are reduced by dLOC for Internet display, blur will be a natural artifact of the reduction process. Blur, when applied to text, also reduces the accuracy of text conversion (OCR) software.

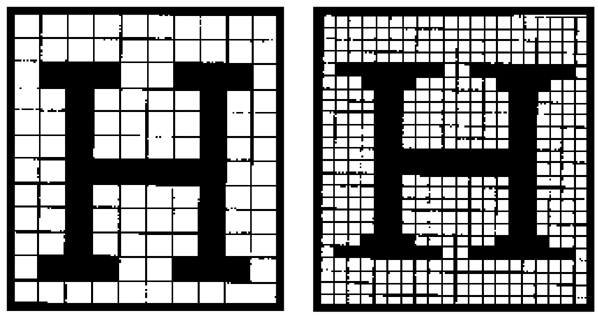
The Rationale for Optical Character Recognition (*Text Generation*)

When a document page is digitized an image of the page is created. All text page images sent to the dLOC's central servers are subject to Optical Character Recognition (OCR).

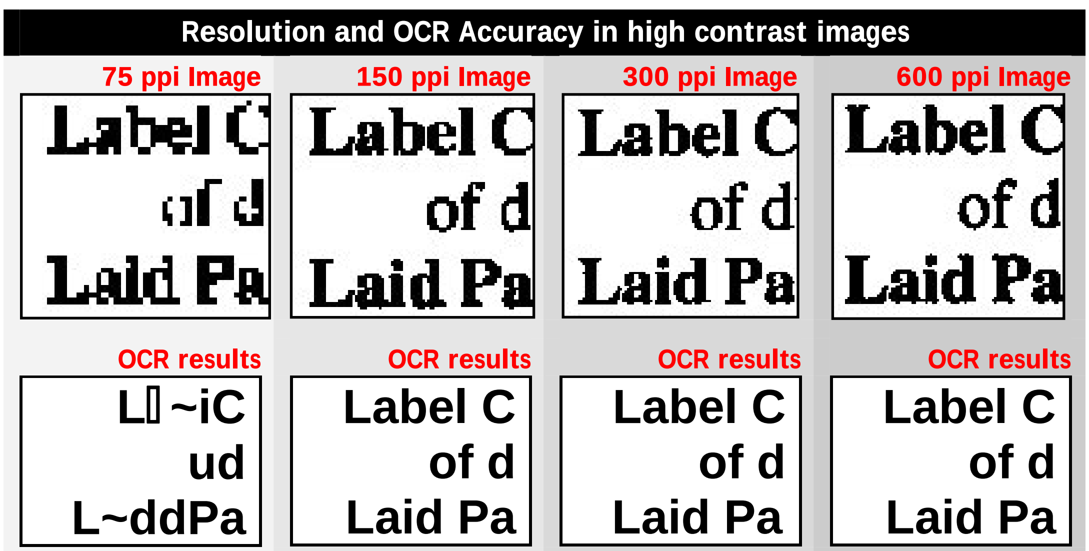
OCR is a process by which page images are converted to searchable text. Several OCR programs are in common use. Most are optimized for the conversion of images digitized with 200, 300, 400 or 600 ppi (80, 118, 158 or 236 ppc). Images created with other resolution can be converted to searchable text but, generally, with less accurate results.



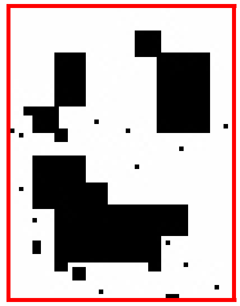
Printed **H**



Digitized text more closely approximates the printed source as resolution increases



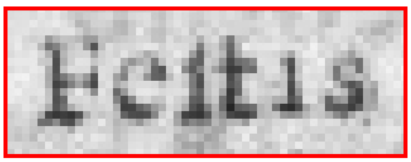
The Importance of Bit-Depth on Text Recognition: the Latin word *Feltis* = Goodness

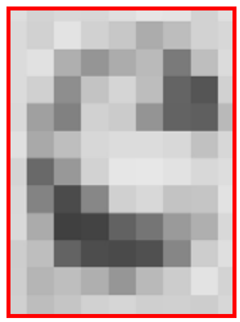


1 Bit Image

This letter may be any of the following: *c – e – o - 0*

If converted to the letter *o*, the Latin *foltis* (leafy, puffy) is formed..





8 Bit Image

This letter may be any of the following: *c – e – o – 0*

But, the arm of the *e* is beginning to become legible.

24 Bit Image

This letter may be any of the following: *c – e – o – 0*

But, the letter *e* appears now to be more probable.

dLOC central servers use the Prime Recognition OCR system, configured with six OCR engines to ensure a high level of accuracy in text generation. For printed texts with normal size fonts, whether plain (*sans serif*) or embellished (*serif*), tests demonstrate that the average modern printed document is accurately recognized at 200 ppi (80 ppc).

dLOC sets a slightly higher standard, 300 ppi (118 ppc), for printed texts with normal size fonts to compensate for occasional uses of small fonts or colored, aged (discolored), or blemished paper.

Digitization of normal printed texts at higher resolution (e.g., 600 ppi/236 ppc), in tests, generally showed no increase in text conversion accuracy. 600 ppi/236 ppc images result in higher conversion accuracy only when the source document is printed with very small fonts.

600 ppi / 236 ppc

dLOC recommends digitizing at 600 ppi (236 ppc) only when working with printed texts with very small fonts; photographs and other continuous-tone graphics, and manuscripts with difficult scripts.

A Rationale for Photographs

Photographs, unlike printed graphics, have continuous-tone. In the source document, one shade or color blends into adjacent shades and colors. Continuous-tone images may be digitized at any resolution. dLOC recommends 600 ppi (236 ppc) resolution to facilitate special uses of images.

Users of digital photographs frequently consult images for their various subjects as for the whole image. A user may want to zoom on the jewelry or hair braids in the photograph of a woman or on shop sizes in the photograph of a street scene. dLOC central servers use JPEG 2000 technology to facilitate zoom. Images digitized at 600 ppi (236 ppc) produce clearer, sharper, and more *readable* images than do 300 ppi (118 ppc) images.

Saving Files and Image Compression

Once the digital image is created, there remains the issue of saving or archiving the file. The digitization technician prefers not to loose a quality image to the imperfections of file saving and image compression routines.

TIFF | **JPEG** | **GIF**

TIFF contains all image data.

JPEG compresses the image, seen here at leaf edges.

GIF also compresses the image, seen here in color patches.

Saving Files

When saving an image file, the technician has a choice of file types, commonly including GIF, JPEG and TIFF. GIF and JPEG (sometimes: JPG) are Internet deliverable file formats. dLOC creates these *derivative* or secondary file formats for participating institutions from a digital master. Institutions either not participating in dLOC or not using dLOC's central servers, should observe similar practice.

Only the TIFF (sometimes: TIF; *Tagged Image File Format*) is considered archival within the international digital library community. It alone serves as a digital master. There are several reasons for this, primarily: image compression. The illustration above demonstrates image quality issues as a factor in file choice.

dLOC Requirement for Digital Master Files.

Save digital master as uncompressed TIFF files, compliant with the current version (*version 6.0*, as of 2006).

For more information on TIFF see: **http://home.earthlink.net/~ritter/tiff/**

Image Compression

When saving an image file, often regardless file type, the technician will be given the opportunity to compress the image. Compression saves file space but has produces other and unwelcome artifacts.

There are two classes of compression: *lossy* and *lossless*.

Lossless compression is an oxymoron. Technically, a lossless image has no compression. A lossless image contains every bit of information created during the scanning process. Here is another simplification: when the scanner captures the bit-stream *1 1 1 1* → the lossless file saves *1 1 1 1*. Though this makes for large files, it also makes for an ideal archival format and, therefore, optimal for file recovery should the digital master ever be damaged in use or degrade in storage.

Lossy data compression technologies attempt to eliminate redundant or unnecessary information, storing a mathematical representation of the eliminated data. Here is yet another simplification: when the scanner captures the bit-stream *1 1 1 1* → the lossy file saves a representation of *4*. Because lossy images generate smaller files, they can be delivered to readers via the Internet quickly. The human eye compensates for image loss by filling in the gaps. But, because there is image loss, recovery from damage or degradation is more difficult and, in many cases, may be impossible without great expense.

Effects of Compression on Image Quality

0% Compression
9 KB file size

No image artifacts

Shown here:
Both as scanned and color enhanced versions.

50% Compression
5 KB file size

Image artifacts appear as dark discoloration at the bridge of the nose, and lightening together with slight blockiness at the temple.

Shown here:
Both as scanned and color enhanced versions.

85% Compression
3 KB file size

Image artifacts appear as blocky discoloration. Compression brings similar colors together, resulting in the block effect.

Shown here:
Both as scanned and color enhanced versions.

