Common Imaging Problems

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Introduction

Every day an increasing number of institutions are digitizing their collections for a host of reasons. Unlike the past, where reformatting was the domain of trained photographers, the availability of scanning equipment has permitted librarians, archivists and volunteers to easily create digital images of varying quality. Digital image quality is hard to define because of the complexity of factors that contribute to and, more often, detract from, our impression of an image. Throughout the capture, processing, and output phases, components of the image are affected by choices the operator makes as well as by the hardware and software used.

Numerous imaging scientists have defined objective technical attributes associated with image quality and the methods for measuring them (Frey). The intention here is not to repeat those efforts, but rather step back and describe the visual characteristics of imaging problems. Although most people can recognize images that have problems, many cannot explain what technical attribute affected their impression of the image. The descriptions that follow should help lay people who are now charged with digitization to better recognize imaging problems and understand what caused the diminished quality, and also provide a common vocabulary for discussing what they see.

Many digital image problems are analogous to traditional photo defects but with new names, while others are unique to digital images. Tone reproduction, resolution, color balance, channel registration, bit depth, noise, clipping, compression and sharpening are the characteristics, effects and activities that will be discussed. Because narrative descriptions are not ideal for describing imaging problems, it is recommended that this be considered in conjunction with the accompanying illustrative poster.
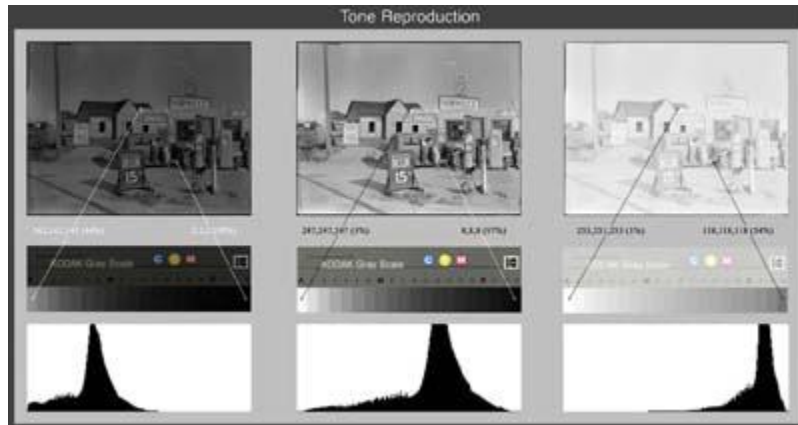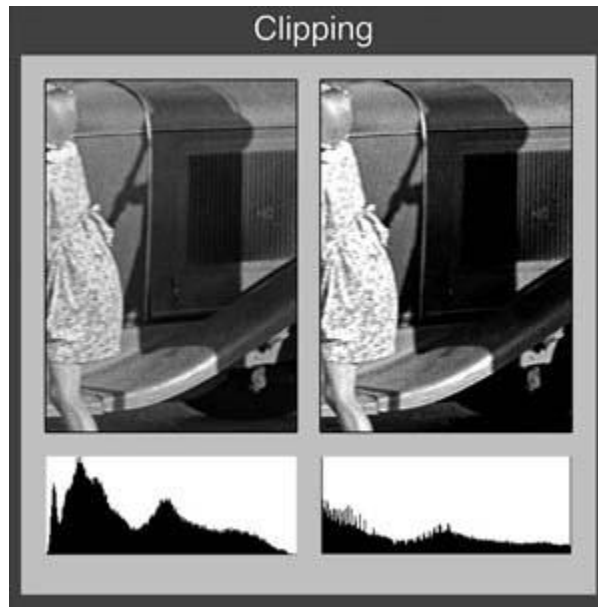

Tone Reproduction

When images are copied, it is essential that the tones, or brightnesses, are properly reproduced. If the tones are too light or dark, or if the relationship between tones is distorted, image quality suffers. This characteristic closely matches proper exposure in traditional photography. If the image is reproduced overall too light, the image will appear washed out and lack dark shadows. If the image is reproduced too dark, the image will appear flat and lack separation of shadow detail. An extreme distortion of the relationship of tones is a localized reversal of brightnesses. This gives the image varying degrees of a solarized appearance and can occur when using tone curve adjustment tools carelessly.

A histogram, available in most image processing software applications, is a graphic representation of the relative distribution of tones in an image. This tool is especially useful for verifying an exposure problem. If the original being reproduced has a full range of tones that are normally distributed (i.e. appropriate quantities of shadow, midtone and highlight pixels with smooth transitions throughout), the histogram should exhibit a relatively smooth shape that extends across the entire width of the graph. If the values in the histogram are concentrated at either end of the graph with a significant amount of the graph devoid of values, this indicates that there has been a problem in the process, and the image quality will have suffered. This does not hold true for originals that already are weighted to one end of the tonal scale often described as high or low key images. In such cases, the histogram should reflect the same preponderance of values at the appropriate end of the scale.

Some of the other image problems to be described are visually reflected in the histogram, so it is a good idea to become comfortable with interpreting the histograms of high and low quality images. Although a histogram alone is not an indicator of quality, it can be helpful in diagnosing an imaging problem.

Clipping

Clipping is an extreme tone reproduction problem deserving its own discussion. Unfortunately, it is very common when operators don't understand the controls in the scanning software and inappropriate settings are selected. It can also occur when auto-correction tools are used in image processing with inappropriate aim values.

When an image is drastically over- or underexposed digitally, the tones at either end of the scale are lost or clipped. When highlight tones are clipped, the light image details are lost and rendered as pure white. This often occurs when textual documents are scanned using document rather than photo settings in the scanner interface. Paper that has texture and color such as ivory or off-white will be rendered without detail or color. Because the scanner may not capture consistently across its bed, this loss may not occur evenly over the entire document, resulting in a mottled appearance. Similarly, scanned photographs may lose highlight detail resulting in large areas of pure white rather than subtle light gray variations. Often, delicate clouds will turn into large white blotches, or light skinned faces will lose subtle features, like cheekbones.

Clipped shadows appear as areas of pure black that lack any detail. Although less common when scanning documents, most consumer level scanners have difficulty capturing detail in dense photographic materials. Dark objects will merge with their shadows, losing shape, and dark hair will fuse into a homogenous black helmet.

Clipping can occur at both ends of the tonal scale simultaneously, particularly when auto corrections are built into the scanning software or are utilized deliberately. The presets are generally intended to give images more snap, but result in the loss of information at the extremes of the brightness range. Clipping is not exclusively a problem with scanners, it occurs in digital photography as well, such as natural scenes with an extreme brightness range or poorly exposed copy photography. Clipping may not appear in all channels of multichannel color images. In an RGB file, for example, information may be lost in only one channel, resulting in retention of some color but loss of detail such as texture.

Clipping can be obscured by the visual complexities of an image, particularly if it occurs in only one channel of a multichannel file, but it is immediately evident in the histogram. If there are values at the endpoints of the graph, clipping has occurred. Normally, the graph should taper and end at (or preferably just before) the endpoints. It is also possible for clipping to occur during capture, and then the high and low values are reset so they are not placed at the extremes of the graph. Within the image, the highlight would not appear pure white and the shadow would not be pure black, but the loss of detail has already happened and is irreversible. This problem would be visually evident in the histogram as a cliff, meaning a completely vertical drop in the pixel count to zero before the end point of the graph, rather than a slope tapering to the end of the graph.


Color Balance

Color digital images, and in many cases monochrome images, are created by the combination of a given number of primary colors as determined by the color model being used. The primary colors must be combined in the proper proportions to create a particular color or, conversely, no color (a shade of gray). Color balance problems occur when the primaries are not mixed correctly and are usually most apparent in the neutral tones of an image.

The analogous problem in traditional photography would be a color cast and would appear as an unwanted color in what should be neutral gray. The color balance problem may be caused by clipping in one or more of the channels, but not necessarily. It may exist over the entire tonal range or only a portion of the range, such as the highlights or shadows. More troubling, it may be a crossover, where it changes from one color at the end of the scale to another, usually opposite color, at the other end.

In a gray balanced RGB color space, such as sRGB or AdobeRGB1998, all three primaries are combined in equal parts to make neutral gray. When the brightness levels are not the same in the three channels, there will be a color balance problem. When an image appears to have color where it should not, whether on the monitor or in printed form, the image file can be checked with an appropriate sampling tool to determine if the problem is within the file or downstream in the rendering process.

Channel Registration
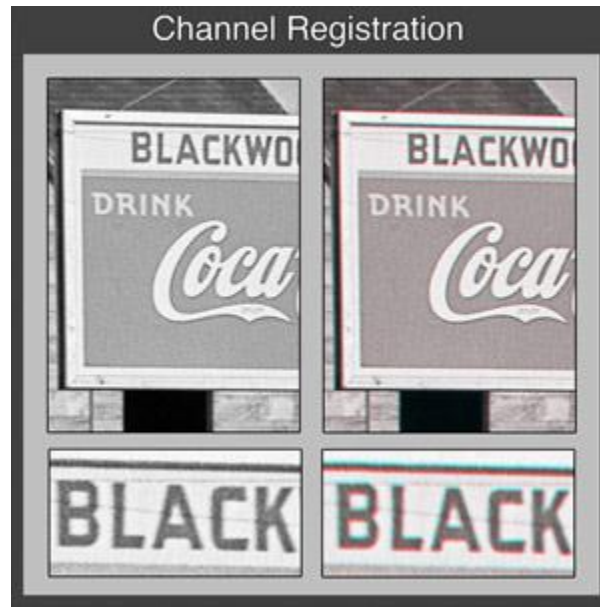
Channel Registration

Not only must the channels carrying the brightness values for the primary colors be combined in the right proportions at any given pixel location to produce the appropriate color, but the channels in their entirety must be properly aligned. If they are not aligned, channel misregistration occurs, which may or may not be readily apparent. If the image contains local areas of high contrast (i.e. hard edges), channel misregistration will manifest itself as color fringing at edges.

This is most evident in images of textual documents where the letters consistently have a color border on one side and usually a second color border on the opposite side. The color fringing may be less obvious in pictorial images unless there are high contrast edges within the image, which are often the boundary between larger areas, therefore the fringe may only be apparent on the lighter side of the edge.
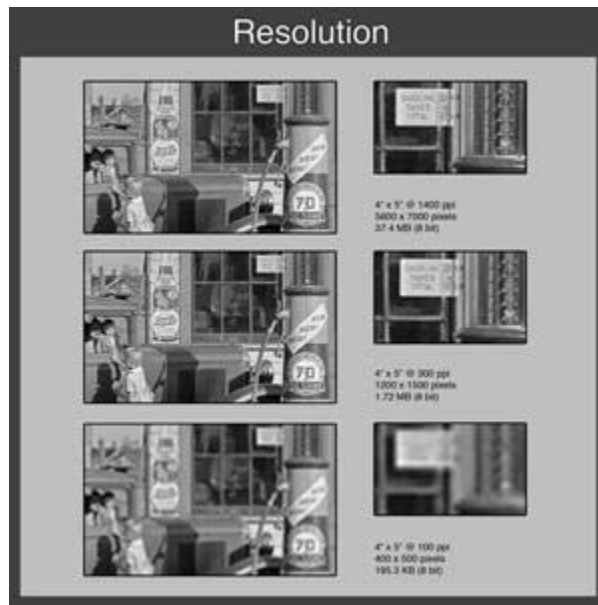
Resolution

Spatial resolution affects quality because as resolution drops, the rendering of fine detail also declines. The perceived effect on quality, however, is dependent on desired viewing magnification. This becomes problematic when the future use of the image is unknown. Determining sufficient resolution becomes a judgment of whether or not expectations of discernable detail have been met. When resolution is low, fine details become blurred. As resolution decreases, larger areas become blocky or pixilated and edges become jagged when viewed at higher magnifications. The concept of low resolution is probably the defect most familiar to the lay person and is likely recognizable without further description.
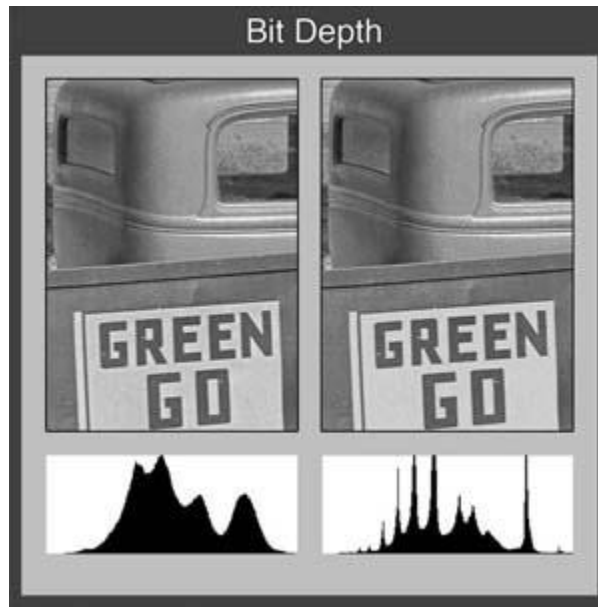
Bit Depth

If low enough, tonal resolution alone can diminish perceived quality, but more often it is a factor in creating unwanted artifacts during image processing. The bit depth of a particular channel determines how many levels of tones are available between maximum and minimum brightness, or between white and black for neutral images with a single channel. When digitizing materials using a low bit depth setting, all tones in the original are forced to a small number of brightnesses, only black or white for 1 bit files (bitonal). This may be done intentionally with textual documents for legibility and storage space savings, but would usually be perceived as low quality when used for continuous tone photographs. The image would have the appearance of a low end photocopy or telefax.

The more common image quality defect associated with bit depth is banding caused by tonal adjustments made to 8 bit per channel files. 8 bits per channel provide sufficient divisions from black to white (256 shades) to create a continuous tone, photographic appearance. However, when extreme adjustments to tone are made to 8 bit files (a total of 24 bits in the case of RGB color images), there are insufficient brightness levels available to maintain the smooth transition between tones that have been stretched apart. This results in multiple tones being compressed into a single brightness. The visual effect is banding or posterization that is most noticeable in smooth gradients or homogenous areas that should have texture. Gradients will break into discrete bands of tone rather than a smooth transition. A textured area will be flattened to a single color or brightness, creating the look of a poster.

The presence of posterization or banding is revealed in the histogram by extreme peaks and valleys in the graph or, even worse, gaps in the shape of the graph (contingent on the original image having a normal distribution of continuous tones). The valleys or gaps are indicative of tones that have been compressed into a single neighboring tone, which grows into a peak because of the additional pixels.
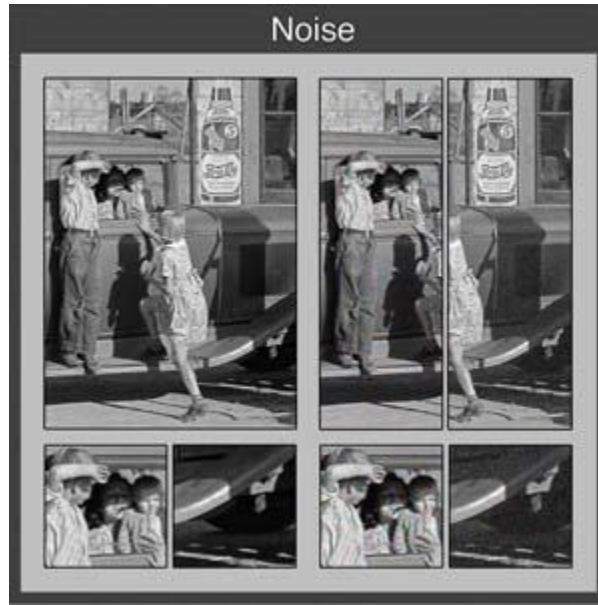
Noise

Noise is described as non-image forming tone variations created by the capture system and is analogous to the perception of graininess in traditional photography. Different capture systems impart noise of varying appearance. Many digital cameras with array sensors create a diffuse color mottling throughout the image when individual primary color receptors are averaged to generate full color picture elements (pixels). High resolution, linear array cameras and scanners are more likely to produce fine (single pixel), full brightness primary color noise that is generally only apparent in shadow areas of an image.

At less than full magnification, noise may not be visually perceptible but can cause an unwanted color cast in local areas. Noise can be particularly troublesome when color correcting an image and unrepresentative noise pixels are used for the basis of balancing color; this would cause global color imbalance. At full magnification, noise can obscure or replace actual image detail, which is certainly a quality loss.
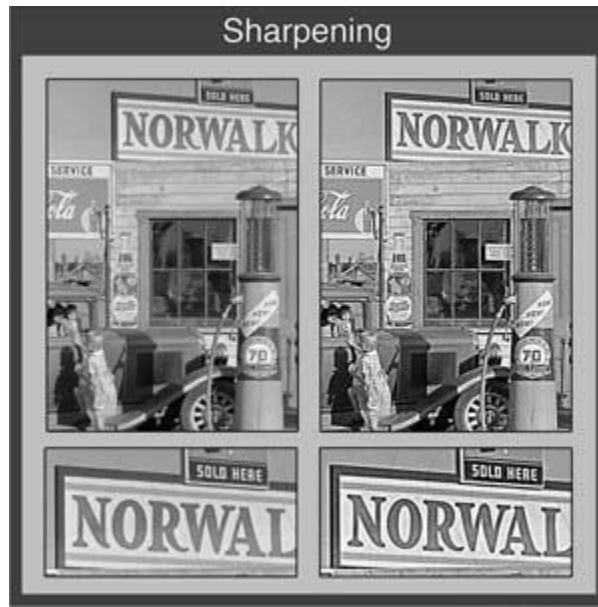
Sharpening

A common image processing step is sharpening to reproduce the apparent sharpness of the original that may be degraded during the capture process. Although undertaken to increase the perceived quality of an image, if not performed judiciously it can actually reduce quality by introducing visible artifacts or causing loss of information altogether.

Sharpening is accomplished by increasing local contrast at the border between tones of a specified difference. Problems usually occur on the lighter side of an edge as it is lightened over a distance from the border. When done subtly, the viewer perceives an increase in sharpness without discerning the trick. If sharpening is excessive, a halo around the edge will become obvious. At the extreme, the area around and edge being sharpened will be clipped and detail will be irreversibly lost. When sharpening becomes distracting rather than enhancing, the perception of quality will diminish.
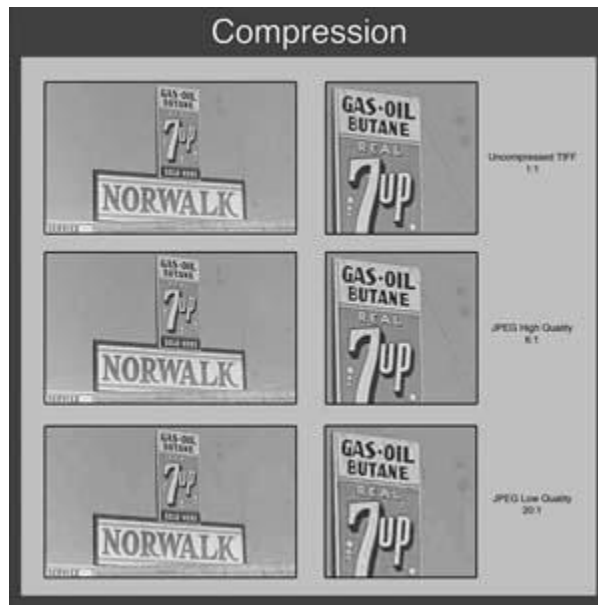
Compression

Compression

Even after every effort has been taken to ensure that a high quality image is produced (still a very subjective overall judgment), the quality can be spoiled by applying glossy compression when the file is saved. In order to save storage space or speed electronic delivery, compression schemes may be employed to reduce file size. Although this can be accomplished using reversible methods, to realize true file size savings, an irreversible method must be used that discards visual information. JPEG compression is still the most prevalent compression scheme used for images, although wavelet and fractal compression are also available.

Like sharpening, careful compression can be subtle and unnoticeable without full magnification inspection. Compression artifacts manifest themselves as blocks of pixels that normally would contain fine variations, but have been averaged to a blurred representation of that area or even a single tone. Neighboring blocks often have distinct edges that begin to define a pattern and visually detract from the image. Fine lines are often lost within blocks or are broken as they cross multiple blocks. This is especially a problem for text contained in images that have been JPEG compressed.

Conclusion

As a wider variety of people undertake digitization with less formal training than traditional photographers, image quality has become more variable. Many people outside the established imaging community who are assigned the task of digitizing lament that the quality of their images are not what they desire, but have trouble identifying causes of their discontent. When searching for solutions, they are faced with a dizzying array of standards and scientific test methods. Without the proper vocabulary, it is difficult to identify which information may be helpful. Once a quality problem can be recognized as a deficiency in a particular attribute or combination of attributes, systematic steps can be taken to improve quality. It is the intent of the preceding discussion to provide a footing to allow further investigation.

References

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