Reconstituting Gradation Using Multiple Photocopier Splits

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A semblance of tonal gradation may be achieved by image summing a series of light and dark first generation photocopies. The relationship between this rendition and that resulting from conventional photography or high-resolution scanning is demonstrated at the proof-of-concept level using a darkroom gray scale.

Introduction

From time to time a better copy of a signature may be needed rather than a regular photocopy, something more photographic (Adams, 1968) and less contrasty, when circumstances prevent obtaining firsthand quality photographs of the original. For example, a particular standard signature may be on a document whose custodian is willing to make and release photocopies of the signature but not the original. On occasion, the client attorney is in the same general area or same town as the document, and offers to take photographs for preliminary use. However, nontechnical photographers or camera buffs may produce rather bad results due to equipment shortcomings as well as lack of experience in this area. Rather than flat-field lenses, they typically use a curved-field lens that may have a macro setting suitable for general close-up photography, or a general purpose lens with no macro pretensions at all on an extension. What is needed is a copier's flat subject field and precise focus, but with the tonality of photographic film.

Some cases involve conditions amenable to the method described in this paper; those conditions being the document's custodian being willing to make (a) multiple enlarged photocopies of the original signature area, at (b) various lightness/darkness settings of the photocopier. These photocopier density splits can be used to make a poor man's photograph. The term "split" refers to any component of a digital image that can be split from it by global arithmetic operations on the digital file, such as the red, blue, and green splits comprising a color image in the RGB additive system, and the cyan, magenta, yellow, and blackness splits in the CMYK subtractive system. The term "grayscale" (one word) is used to describe continuous-tone monochromatic images, usually 8-bit digital (256 levels of intensity) although higher power-of-two ranges are occasionally encountered such as 10-bit (1024 levels); the images are comparable to what are ordinarily thought of as black and white photographs. The similar expression "gray scale" (separate words) as used here refers to a photographic darkroom reference accessory depicting a series of stepped grays from black to white, such as found on the Kodak card. In the technique presented here, the various splits as well as the final composite are all grayscale images of an object called a gray scale.

In practice, the technique better separates the light tones and is comparatively deficient in "seeing into" the dark gradations, and thus is more likely to produce pleasant surprises in the form of raised indentations (via shadows dimly captured by the photocopier) than in the deeper shades within written lines. However, the increase in image detail usually results in a more photographic continuous tone rendition of burr striations and curve-exiting ink goops in ballpoint signatures and other details such as clarification of crossing or interfering marks or printing. The increase in information content results both from the enlargement (usually from ~1.3X to ~2X) and from the density slicing of the original.

Methods and Materials

Various methods can be used to blend the light/medium/dark copies (typically at least three copies are furnished in response to the request for copies at every light/dark setting of the copier; some copiers have as many as nine such settings). High resolution (1200 x 1200 dpi) scans are run for each photocopy (each being a split), and the results are digitally overlaid in register and blended with any image processing software capable of making fine angular adjustments of layers or objects such as Adobe Photoshop or PhotoImpact. The image merging can be done with the program's internal tools or with The Image Processing Tool Kit (Russ, 1996). The Russ toolkit is a CD collection of Photoshop-compatible plug-ins, among them the Intensity Profile function used for Figures 2, 4, and 6.

Summing (Daniels, 1987) the digital images usually produces as good a result as more complicated schemes such as generating darker layers from the lightest scans. If a simple blend is used, two of the three splits are blended 50-50, followed by a 67-33 blend with the third split, resolving most ink writing into levels of gray and often producing graduation of the light tones of the paper substrate as well. Note, however, that undue contrast enhancement of the light tones, as might result from equalization of the blend, could confuse surface artifacts of the splits themselves with near-whites of the original latently captured in the photocopies. The lightest tones may be of particular interest for examining creases, folds, or indentation shadows. The noise-suppression advantages of image summing apply to a limited degree (reduction of raggedness and toner particle grain) when summing the individual photocopies. It should be noted that defects such as copier glass scratches, which are nonrandom and common to each split, add at the same rate as signal (information content shared by the splits). If resolution and noise reduction are of particular concern, shifting the original on the copier glass between splits could be specified when making the photocopy splits. However, angular displacements (rotations of the original between copies) are not advisable due to the increased manipulations necessary to perfectly align the splits if they prove to be anisotropic, although if the copier is prone to streaks the complications involved may be worth it.

Results

Figure 1 represents a scanner's photographic rendition of the graduated steps in a Kodak (1975) gray scale card. Figure 2 represents a linear intensity plot of the steps in the scale. The intensity plot converts the pixel values to a line profile that records the signal strength as a function of position, averaging all pixels in each vertical column of the image. Note the evenness of the steps depicted in Figure 1 and plotted in Figure 2. Compare the relative unevenness of the steps of the five photocopies of the gray scale card depicted in Figure 3 and their respective intensity plots shown superposed with each other in Figure 4. Resolution not being a consideration for this demonstration, the regular 1:1 life-size copier setting was used, and scans were made at 400 dpi.

None of the individual photocopies resolves all ten steps of the card, the Konica 5503 Copier used here being only able to separate (meaning that it is able to depict as visibly different shades) approximately six steps at any given light-dark setting, the separation extending farthest into the darkest steps at the lightest setting, at which the lightest steps fade to white, while the lightest steps are resolved at the darkest setting, at which the darkest steps merge into blackness. Note in the intensity plots how each photocopy emphasizes separation in a restricted range of densities and suppresses separation elsewhere; allowing contrasty, legible copies to be made of widely varied originals, for which the trade-off is the sacrifice of a long photographic tonal scale. Figure 5 is the gray scale card reconstituted by summing the five individual photocopies of the scale shown in Figure 3. When comparing Figure 5 with the grayscale scan of the card in Figure 1, it can be seen that the number and evenness of gray shades illustrated in Figure 5 and graphed in the corresponding intensity plot, Figure 6, are superior to those at any single light-dark setting illustrated in Figure 3 and graphed in Figure 4. The quality of the resulting synthesis is estimated to be approximately equivalent to a 6-bit gray scale image.

Conclusion

In conclusion, when examining details of handwriting on documents, whether live through

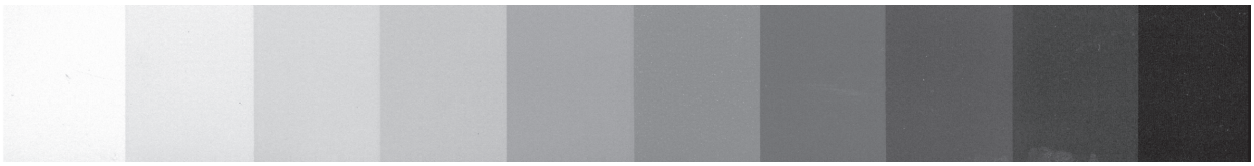

Figure 1. A darkroom photographic gray scale card as captured by a scanner (reproduced from a laser print, as are Figures 3 and 5), a process which delineates all ten steps of the scale.

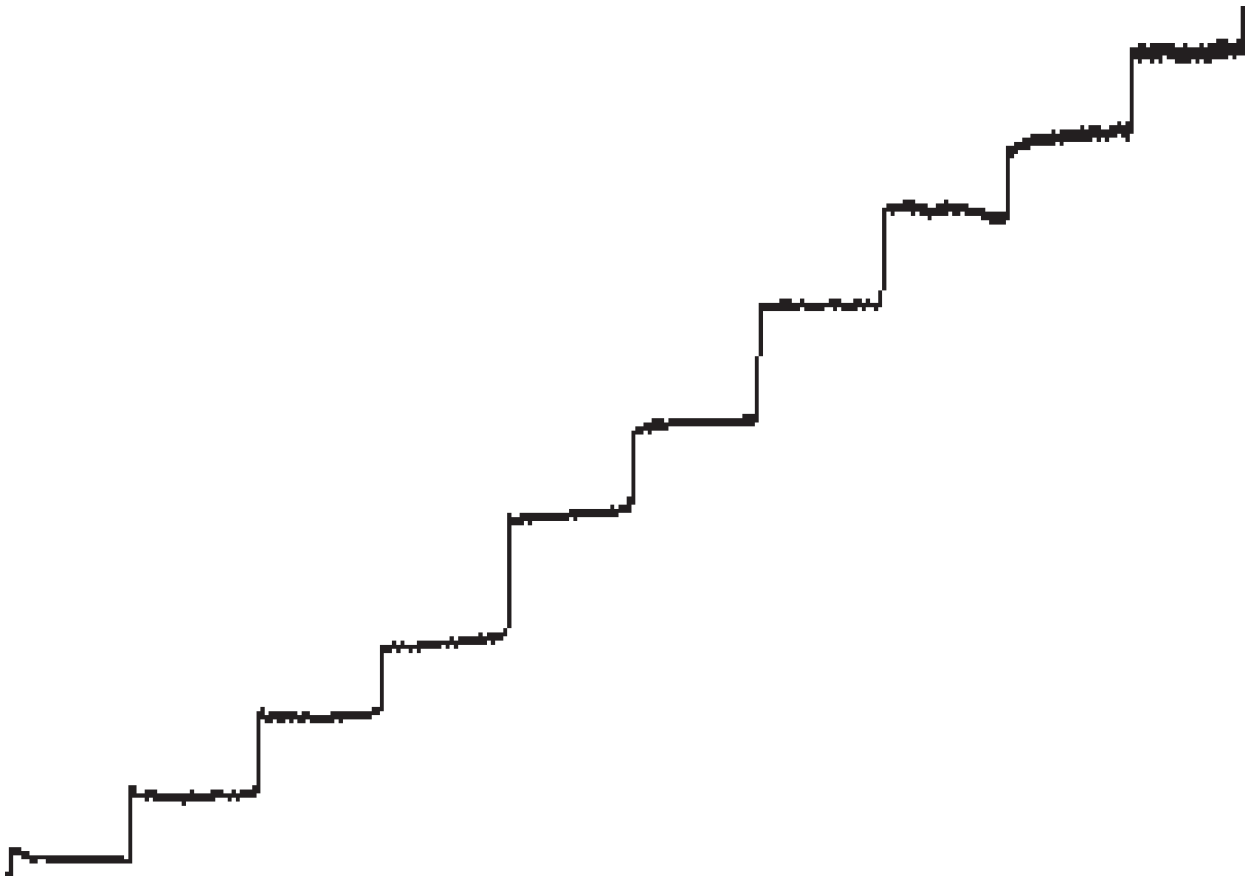

Figure 2. Intensity plot of Figure 1's scanner image, from digital white (255) at bottom of vertical axis to maximum intensity black (0) at top.

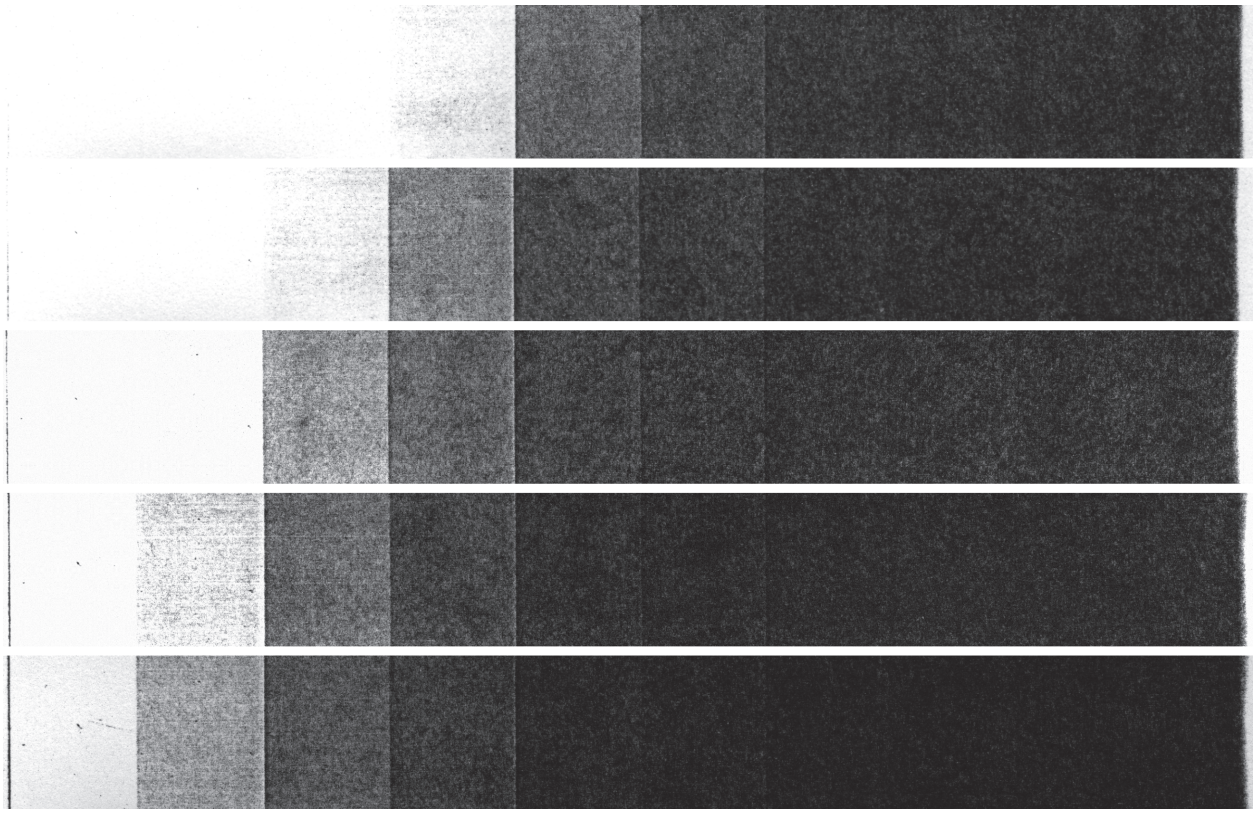

Figure 3. The same gray scale card as reproduced by a photocopier at five light-dark settings. Resolution not being a consideration, the regular 1:1 life-size copier setting was used. No single copy resolves all ten steps of the Kodak card, although the copier used in this demonstration was able to separate (depict as visibly different shades) approximately six steps at any given light-dark setting, with the separation extending farthest into the darkest steps at the lightest setting at which the lightest steps fade to white, while the lightest steps are resolved at the darkest setting at which the darkest steps merge into blackness.

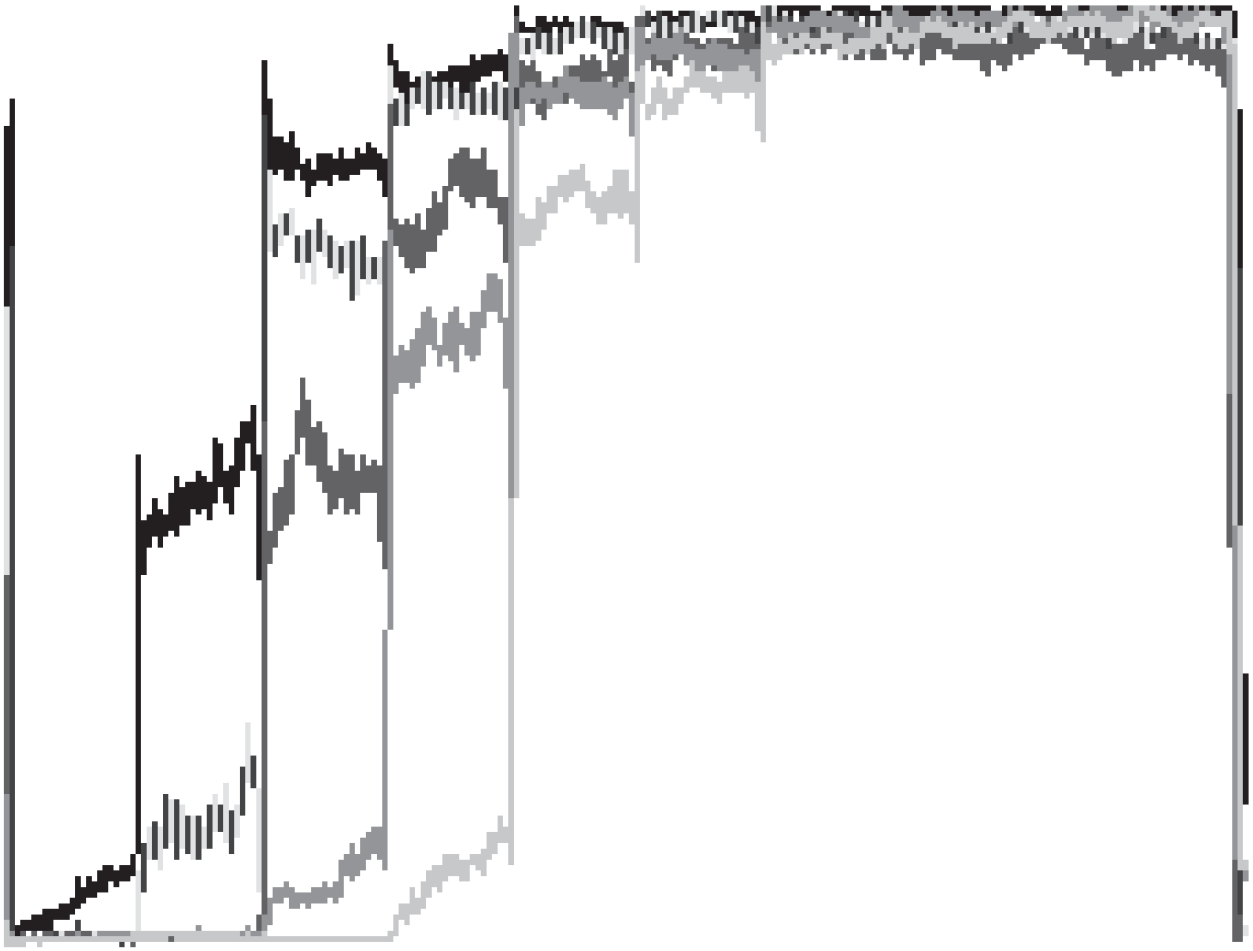

Figure 4. Intensity plots of the five photocopies: lightest gray equals lightest (top bar of Figure 3), light gray equals second lightest, medium gray equals third lightest, vertical dark and faint gray bars equals fourth lightest (middle default setting on Konica 5503 copier); black equals darkest equals fifth lightest (bottom bar of Figure 3). Note that each emphasizes separation at a certain darkness and suppresses separation elsewhere allowing contrasty, legible copies to be made of widely varied originals, for which the trade-off is the sacrifice of a photographic tonal scale.

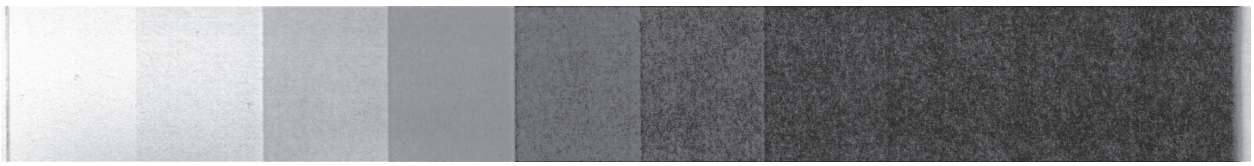

Figure 5. Gray scale card as reproduced by summing the five photocopies shown in Figure 3. Tonal scale is superior to any of the copies and comparable to the grayscale scan of Figure 1.

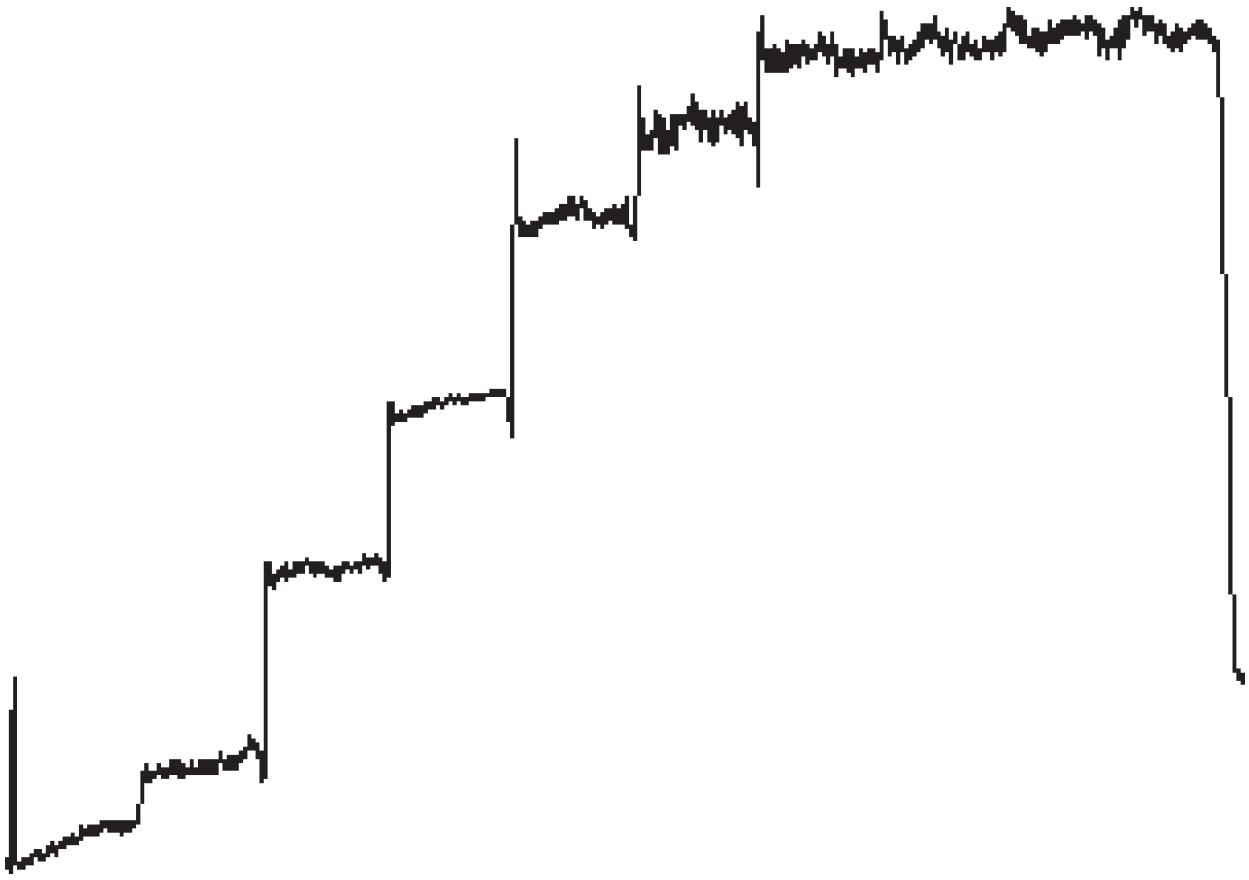

Figure 6. Intensity plot of Figure 5's reconstituted image. The number and evenness of gray scale steps are superior to that at any single light-dark setting plotted in Figure 4, and more like the photographic rendition (8-bit grayscale scan) of the same gray scale card shown in Figure 1 and plotted in Figure 2.

the microscope, or as photographic transparencies, or via monitor-displayed digital color or grayscale images, it is helpful to maximize shadow detail, allowing the observer to look "into" the tones of written lines. To that end, the technique outlined in this paper can be useful in that it allows grayscale images to be reconstituted from a series of ordinary photocopies.

References

Adams, Ansel (1968). *The Negative and Artificial-Light Photography.* Hastings-On-Hudson, NY: Morgan & Morgan, Inc.

Daniels, James R. (1987). Image Summing, *Journal of the Southwestern Association of Forensic Scientists*, Vol. 9, No. 1, pp. 34-35 and *Midwestern Association of Forensic Scientists Newsletter*, Vol. 16, No. 1, pp. 43-47.

Russ, John C. and Russ, Chris (Copyright 1996-8). The Image Processing Tool Kit. (CD) ISBN #1-928808-26-3.

Kodak Gray Scale (Copyright 1975). Eastman Kodak Company, Rochester, NY 14650.