Recent Developments in Black and White Conversion

A Technical Analysis of the New Black and White Adjustment in Photoshop CS3

by Michael Chamberlain

Contained in the latest release of Photoshop, Camera Raw, and Adobe's new Photoshop Lightroom is a new method for converting color images to black and white from the RGB color space. This new adjustment is called, simply, "Black and White," and is clearly intended by the Adobe engineers to be the preferred method of black and white conversion as evidenced by the new warning that appears when you convert from the RGB to grayscale color mode:

> *Discard color information?*
> *To control the conversion use*
> *Image > Adjustments > Black & White*

This tool has been met with critical acclaim and has been quickly accepted by the Photoshop community because of its ease of use, control, and apparent high quality conversion.

Within this article, we will take an in-depth look at the tool, its mathematics, its controls, and take a purely objective look at its ability to produce high-quality conversions. Let us begin by looking at the equation within the scope of its RGB input.

$$o = 127.5\Bigg(\frac{\left(atan2\left\{\frac{\sqrt{3}}{2}(G-B),\frac{1}{2}(2R-G-B)\right\}\right)-60\left\lfloor\frac{atan2\left\{\frac{\sqrt{3}}{2}(G-B),\frac{1}{2}(2R-G-B)\right\}}{60}\right\rfloor}{60}\Bigg)\Bigg(\Bigg(\Bigg(\Bigg(1-\frac{\sqrt{\left(\frac{\sqrt{3}}{2}(G-B)\right)^2+\left(\frac{1}{2}(2R-G-B)\right)^2}}{\max(R,G,B)/255}\Bigg)$$

$$\frac{\max(R,G,B)}{255}+\frac{\max(R,G,B)}{255}\Bigg)+\Bigg(2\frac{\max(R,G,B)}{255}-\Bigg(\Bigg(1-\frac{\sqrt{\left(\frac{\sqrt{3}}{2}(G-B)\right)^2+\left(\frac{1}{2}(2R-G-B)\right)^2}}{\max(R,G,B)/255}\Bigg)\frac{\max(R,G,B)}{255}+\frac{\max(R,G,B)}{255}\Bigg)\Bigg)$$

$$(2v_{\left\lfloor\frac{atan2\left\{\frac{\sqrt{3}}{2}(G-B),\frac{1}{2}(2R-G-B)\right\}}{60}\right\rfloor}-1))+127.5\Bigg(1-\Bigg(\frac{\left(atan2\left\{\frac{\sqrt{3}}{2}(G-B),\frac{1}{2}(2R-G-B)\right\}\right)-60\left\lfloor\frac{atan2\left\{\frac{\sqrt{3}}{2}(G-B),\frac{1}{2}(2R-G-B)\right\}}{60}\right\rfloor}{60}\Bigg)\Bigg)$$

$$\Bigg(\Bigg(\Bigg(1-\frac{\sqrt{\left(\frac{\sqrt{3}}{2}(G-B)\right)^2+\left(\frac{1}{2}(2R-G-B)\right)^2}}{\max(R,G,B)/255}\Bigg)\frac{\max(R,G,B)}{255}+\frac{\max(R,G,B)}{255}\Bigg)+\Bigg(2\frac{\max(R,G,B)}{255}-$$

$$\Bigg(\Bigg(1-\frac{\sqrt{\left(\frac{\sqrt{3}}{2}(G-B)\right)^2+\left(\frac{1}{2}(2R-G-B)\right)^2}}{\max(R,G,B)/255}\Bigg)\frac{\max(R,G,B)}{255}+\frac{\max(R,G,B)}{255}\Bigg)\Bigg)(2v_{\left(\left\lfloor\frac{atan2\left\{\frac{\sqrt{3}}{2}(G-B),\frac{1}{2}(2R-G-B)\right\}}{60}\right\rfloor+1\right)}-1))$$

This equation is applied to each pixel within the image* producing an 8-bit output (o) based on the input values of the red(R), green(G), blue(B) channels and the values of the six tool sliders red($v_{0,6}$), yellow(v_1), green(v_2), cyan(v_3), blue(v_4), and magenta(v_5). Any resulting value greater than 255 or less than 0 are clipped.

At first glance, this equation looks extremely complicated, and the engineering theory behind it sounds like an ideal method of pulling the data out of the RGB channels to create an easily controllable black and white conversion that produces extremely high quality using all the data from all three channels. Let us analyze this equation and see if we can't break it down and see what makes this tool tick.

One might notice that there are three equations that repeat several times in the above formula:

$$h = atan2\left\{\frac{\sqrt{3}}{2}(G-B), \frac{1}{2}(2R-G-B)\right\}$$

$$s = \frac{\sqrt{\left(\frac{\sqrt{3}}{2}(G-B)\right)^2 + \left(\frac{1}{2}(2R-G-B)\right)^2}}{\max(R,G,B)/255}$$

$$b = \frac{\max(R,G,B)}{255}$$

These are the equations used to convert RGB into the HSB color space. Taking these new variables into consideration, we can simplify the formula to:

$$o = 127.5(\frac{h - 60\left\lfloor\frac{h}{60}\right\rfloor}{60})(((1-s)b+b) + (2b - ((1-s)b+b))(2v_{\left\lfloor\frac{h}{60}\right\rfloor} - 1)) +$$
$$127.5(1 - (\frac{h - 60\left\lfloor\frac{h}{60}\right\rfloor}{60}))(((1-s)b+b) + (2b - ((1-s)b+b))(2v_{(\left\lfloor\frac{h}{60}\right\rfloor+1)} - 1))$$

This form is much more manageable, and makes it much easier to recognize how each aspect of the color data is used in producing the output. However, it is at this stage of the analysis that the first fundamental problem with this method becomes apparent. If we look at how the hue affects the image, we can see that the hue data itself is not being factored into the conversion. The hue of the pixel is used as a means to select which two sliders are being used and to weight how much each sliders affects the output.

Each slider represents a point located at even 60° increments around the polar color grid. Each slider also has an affect on nearby color values which diminishes linearly for 60°, giving each slider a 120° range of influence. In order to apply this influence, the formula contains calculations to determine how far a given hue is from each of the neighboring control points. This distance is represented as a percentage:

$$d = \frac{h - 60\left\lfloor\frac{h}{60}\right\rfloor}{60}$$

By assigning this calculation to the variable "d" we can further simplify the equation to:

$$o = 127.5d(((1-s)b+b) + (2b - ((1-s)b+b))(2v_{\left\lfloor\frac{h}{60}\right\rfloor} - 1)) + 127.5(1-d)(((1-s)b+b) + (2b - ((1-s)b+b))(2v_{(\left\lfloor\frac{h}{60}\right\rfloor+1)} - 1))$$

* *With the exception of pixels with an RGB value of <0,0,0>, which retain that value.*

It is at this point that I'd like to reformat the equation slightly:

$$o = d(127.5((1-s)b+b) + (255b - 127.5((1-s)b+b))(2v_{\lfloor \frac{h}{60} \rfloor} - 1)) + (1-d)(127.5((1-s)b+b) + (255b - 127.5((1-s)b+b))(2v_{(\lfloor \frac{h}{60} \rfloor + 1)} - 1))$$

It is at this point that the first truly damning aspect of the equation becomes evident in the form of another important Photoshop equation:

$$u = 127.5((1-s)b+b)$$

This equation is the calculation used to desaturate an image when converting directly from RGB to Grayscale.

Based on this realization, we can simplify the equation still further:

$$o = d(u + (255b - u)(2v_{\lfloor \frac{h}{60} \rfloor} - 1)) + (1-d)(u + (255b - u)(2v_{(\lfloor \frac{h}{60} \rfloor + 1)} - 1))$$

Based on this breakdown, we now find that the equation is made up of three parts, a grayscale conversion, a percentage adjustment based on the slider value, and a modulation calculation to soften the effect as the brightness value changes in the image.

Because the stated slider value requires an adjustment to reach the final value used in the equation, for simplicity, we will assume that adjustment into the slider value:

$$v_{\lfloor \frac{h}{60} \rfloor} = (2v_{\lfloor \frac{h}{60} \rfloor} - 1)$$

Resulting in the following equation:

$$o = d(u + (255b - u)v_{\lfloor \frac{h}{60} \rfloor}) + (1-d)(u + (255b - u)v_{(\lfloor \frac{h}{60} \rfloor + 1)})$$

We can also represent the modulated maximum brightness value as:

$$m = 255b$$

This results in the final equation:

$$o = d(u + (m - u)v_{\lfloor \frac{h}{60} \rfloor}) + (1-d)(u + (m - u)v_{(\lfloor \frac{h}{60} \rfloor + 1)})$$

If we dig down deep enough into the Black and White tool, we actually discover the very equation it is reputed to replace. As a practical demonstration of this flaw, we find that setting all the sliders in the black and white adjustment to 50 produces a result identical to a straight grayscale conversion.

Taking this into account, we can now see that despite the complexity of the formula, and the undeniable brilliance of the theory behind the conversion, in practicality it involves the subsequent application of two unacceptable practices. Straight desaturation of the image, followed closely by a form of frequency modulation. The slider values are converted into a percentage based slide of the brightness data of the desaturated image. Essentially throwing away 2/3 of your data and compressing what little information you have left.

A further limiting factor of this method is the 120° range of influence of the sliders. Moving sliders that are 120° apart will result in neighboring values being manipulated by independent processes, frequently producing artifacting or worse, hard edges.

While vastly superior to a flat grayscale conversion, it is none-the-less a woefully flawed attempt to provide a simple method of conversion.

Considering the availability of features in Photoshop that can produce a black and white conversion that use the entire dataset and don't compress the tonal values this tool ends up not only failing to live up to the hype, but actually manages to commit the "crimes" it was intended to prevent. The oldest and most versatile alternative is channel mixer, which is based on the simple formula:

$$o = R(r) + G(g) + B(b) + C(255)$$

Working as a function of the slider values (R,G,B) and the channel values (r,g,b) mapped to the gray channel. Provided you avoid using the constant modifier (C), which introduces frequency modulation into the calculation, this method has the best data integrity, versatility of output, and utilization of the source data of any conversion method.

The final verdict on the Black and White Adjustment:

Avoid this tool, it's a lot of hype wrapped up in an idea that sounds clever, but falls apart in practical use. There are several better methods, use them instead, "Black and White" isn't worth the drawbacks.

