Interactive image-enhancement for the desktop printing of digital photographs

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Abstract

The proportion of digital photographs that are printed at home by the consumer continues to plummet, and commercial printers continue to capture an increasing share of this market. A principal reason for this trend is due to the frustration expressed by consumers over their disappointment with the quality of desk-top prints, and their inability to effect the outcome, since the tools provided by the desk-top printing industry are generally inadequate, technically complicated or ineffective. This dissatisfaction is compounded by the fact that the digital camera industry has not yet provided either image-acquisition technologies or post-processing facilities that allow the consumer to control the rendition of flesh tones and faces to personal preference, long known to be the key to consumer satisfaction. The author will describe the basic imaging principles brought together for a simple user-friendly solution to this problem, allowing custom selection of flesh tones by non-technical consumers on the basis of individual preference. Results from among those for a large number of typical consumer images will be demonstrated.

Introduction

Two years ago at this same conference, the author described a consumer digital-image enhancement methodology and interface based entirely on an intuitive user-friendly *image-choice-only* operation [1]. This ease of operation by an unskilled user was also demonstrated to allow critical-path navigation through as many as a million-plus possible individual image-quality states within a matter of seconds. It was observed that the core image-enhancement methodology was restricted to *determinate* pixel mapping, allowing error-free transport through these many image-quality states, and thus, for example, an exact path-reversal back to the original image without accumulated signal-to-noise deterioration other than by inevitable quantization error. This was made possible by the definition of a set of orthogonal image vectors, and describing all excursions in image-quality in terms of constant visual space. The author also demonstrated the crucial role of linearizing the increments of the image vectors, and showed that each vector could be represented in terms of these identical absolute increments. Further the practical concept of the Just Appreciable Visual Difference (or JAVD) was introduced, relating to a consumer preference scale-increment for the image quality of digital images (not to be confused with the term JND, as used extensively in visual psychology).

In the above terms, our previous contribution concentrated heavily on the image quality vectors relating to brightness and contrast. In this present contribution we now concentrate exclusively on the problem posed by specifying color variations in this way, and defining an entirely practical color scale and interval so that color selection can be as easily presented for personal choice to the average consumer, as could other basic image-quality variables. This posed a quite considerable challenge, since the literature on color reproduction and color preference is a weighty one, and the mere task of specifying a color transformation methodology is far from straightforward. However, our approach was to bypass this large body of knowledge and to attempt to apply exactly the same analytical approach to the individual color (RGB) vectors that had worked so successfully with the brightness and contrast vectors, since the latter had proved especially robust in the absence of formal image brightness or contrast theory, as such.

The practical range of the set of orthogonal vectors, as selected to encompass the key physical variables associated with a digital image, was determined in a pragmatic manner based on the reality of the statistical image-base that it was desired to describe. For this several thousand typical consumer digital images were originally selected, covering all realistic image-quality levels, acquisition devices (cameras, scanners, cell-phones), scene and lighting types, and their relevant statistics were compiled. This same validation set of images likewise covered the practical gamut of scene (and facial) types, and spanned a wide range of practical image-quality levels and conditions of color balance. Thus the pictorial database was already at hand to test the hypothesis that color-correction could be treated in exactly the same manner as for example, image brightness and contrast.

The results of our practical consumer-base validation data were found to be in broad agreement with a subsequent data set published on the internet [2], covering expressed dissatisfaction with several million digital prints, and summarized here in Figure 1.

This same data source also confirmed that consumers typically made these judgments of image-quality failure largely on their inspection and satisfaction of flesh tones in general, and facial reproduction specifically.

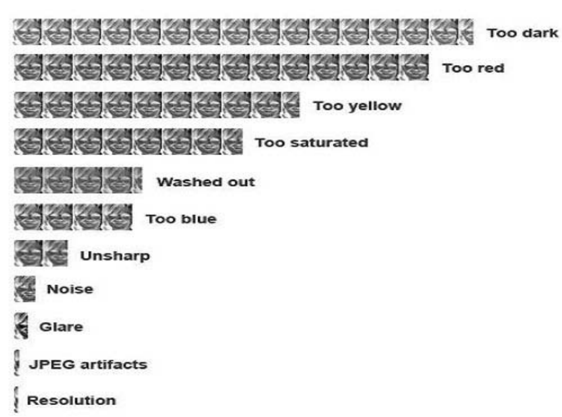

***Figure 1**. Practical data on consumer satisfaction with digital prints.*

The Color Enhancement Approach

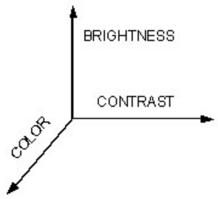

Figure 2. *Orthogonal digital image-quality vectors.*

The schematic shown in Figure2 illustrates the broad hypothesis behind the present approach. The main assumption is that the defined orthogonal vectors for brightness, contrast and color can all described in the same space, and although the ranges of these vectors may differ to match the overall extent of the practical data set, all may be defined on the same incremental scale within this overall image-quality 'space'. Naturally, in the color case, the scale may be applied equally to each of the color (RGB) components as appropriate. Within this latter assumption, a basic increment of color balance is no different than a basic increment in image brightness.

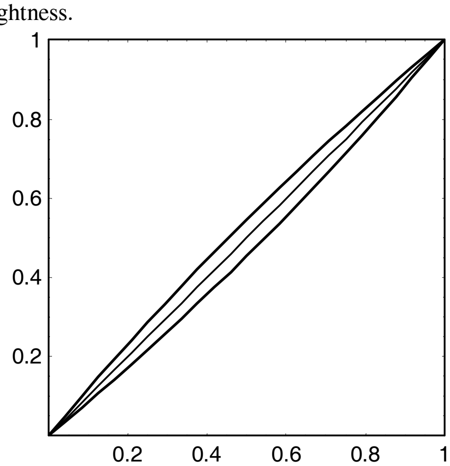

***Figure 3**. Pixel mapping function used on individual color components.*

Figure 3 shows this basic increment of color change, in terms of the corresponding (normalized) pixel mapping function, to be applied appropriately to the R, G or B components. In this same sense the mapping function to the left of the forty-five degree line may be thought of an increase in this component, while that to the right being a decrease.

Color corrections based on the increments of Figure 3 were tested on a large sample sub-set of the overall consumer images described above, where this sub-set consisted of the wide range of color misbalances. The effectiveness of the color corrections and the statistics of the necessary degree of correction were noted, and it was that found successful corrections could be made to the overwhelming majority of consumer images originally having unsatisfactory color balance.

The conclusions from this validation exercise confirmed the orthogonal assumptions of the overall methodology, and can be summarized as follows:

a) The color correction interval as represented in Figure 3 was confirmed as representing the basic interval of color (JAVD) below which the user became indifferent to the degree of change.

b) Suitable (RGB) combinations of these unit changes allowed satisfactory practical corrections of color balance according to user preference for digital images having original misbalances that ranged from subtle to severe.

c) The overall change made by a combinations of these RGB intervals is independent of the order in which they have been applied.

d) All such changes are substantially error-free, and thus reversible by applying the sequence of changes (in any order) of opposite effect.

e) Typically the number of combined interval changes for the majority of consumers to reach final preference fell in the range of one to four overall, with a very small minority of images calling for as many as ten such changes.

With hindsight, the fundamental reason for these 'well-behaved' characteristics of the practical color corrections arises from the much more restricted range that is necessary for effecting satisfactory color change, than the ranges found for brightness and contrast change. Thus, the orthogonal assumption underlying Figure 2 was most closely observed in practice for changes in color. This is not to say that users attempting to correct facial or overall preferred appearance did not sometimes first make significant changes in brightness and contrast (in fact, by definition, for many image types it was simply not possible to do so), but merely to state that color changes *per se* were found to have all the practical virtues listed above in the overwhelming majority of practical cases.

Practical Implementation

***Figure 4**. Typical user-interface and color image-choice menu.*

Figure 4 shows the typical user-interface incorporated in the choice methodology. The JAVDs of the color increments were combined to give the user the choice of a range of color corrections observed to be as yielding from 'cold' to 'warm' flesh-tones. By extending this scale to left and right, for example as presented in a movable film-strip, the user could readily control and choose from a large number of color states, according to personal preference.

***Figure 5**. Typical user correction for color balance.*

A typical user choice of preferred facial reproduction is shown in Figure 5. In this case the user was in fact satisfied with the image as originally acquired, but given the easy choice of a series of color balance alternatives close to the original, readily opted for the lower image in preference to the original upper image. This was the practical experience with a large proportion of similar images, and especially those in which faces played a predominant role in the image. Given a simple choice of color balance alternatives, the typical consumer had a preference other than that presented by the acquired image. This practical conclusion was as relevant for images acquired with the simplest and cheapest devices, as it was for those acquired with the latest and most sophisticated generations of digital cameras, portable devices and scanners. In fact these latter acquisition devices present the optimum opportunity for successful image-quality enhancement, due on the one hand to their inherent signal-to-noise capabilities, and yet on the other hand, the unknown nature of preferred user reproduction. In this context, it should be noted that software versions of our user choice technology, operating with results as illustrated, currently occupies only around 200kbs for a standard digital camera version, and that an effective cell-phone version is currently being tested at 30kbs.

Figures 6 and 7 show examples of classes of consumer images that need more extreme corrections, and yet for which the consumer has no user-friendly way of rapidly achieving the desired result. A significant number of the hundreds of billions of images in consumer possession fall into this category, and due to their lack of image-quality are not used for further purposes, including printing, desk top or otherwise.

***Figure 6**. Consumer image requiring a large color balance correction.*

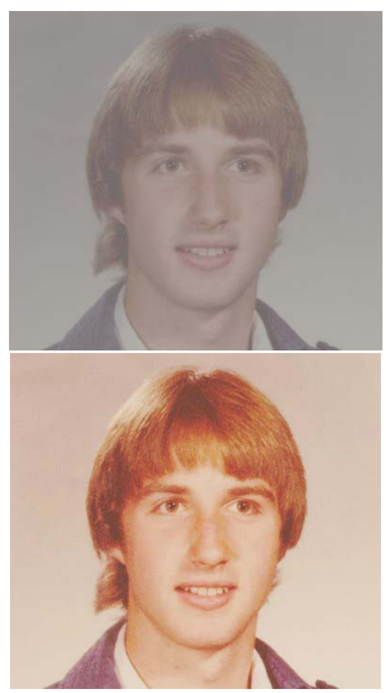

***Figure 7**. Restored image of an scanned faded photograph.*

Summary and Conclusions

We have described the concepts and operating principles of a practical color image-enhancement methodology designed specifically for technically unsophisticated consumers. This methodology has been successfully tested on a large number of typical consumer images acquired from a wide variety of acquisition devices.

Individual preference for image quality is tied closely to the perception of faces and flesh-tones, and in turn, this defines the preferred color balance. In this context we have described a simple color–balance choice methodology, as part of an overall user-friendly enhancement procedure. This color methodology was designed from first principles using the same approach as that employed for the correction of the brightness and contrast attributes of consumer digital images. By virtue of its ease of operation and the real-time error-free nature of the color-correction procedure, it can readily be inserted in appropriate software form anywhere a consumer interacts with a digital image, from camera, mobile device, printer, or scanner, to web or photo-kiosk.

The overall enhancement methodology was based on describing the image characteristics (brightness, contrast, color) by a framework of orthogonal vectors covering the image quality volume appropriate for a large consumer database of typical digital images. It was found that vectors describing color balance could be defined within this overall set, and in such a way that small absolute increments could be translated into user control, enabling rapid choice of preferred color balance. Thus consumers could readily achieve their preferred facial color, typically several absolute increments away from that acquired by the digital device.

From a large number of digital images corrected in this way, it was also noted that scenes in general, and facial characteristics in particular, could not be controlled by preferred changes in color balance alone, but usually also involved the balancing of the brightness and contrast image quality components.

References

[1] Rodney Shaw and Paul Johnson, Image-processing for the digital consumer market.

[2] See data provided at: www.smugmug.com

[3] See practical examples at: www.whiterosedigital.com

Author Biography

Rodney Shaw has a PhD from Cambridge University. His career in imaging research and education includes over a hundred publications, and recognition by IS&T Honorary Membership in 2002. In 2006 he co-founded White Rose Digital, an internet provider of digital-imaging solutions for consumers, where he currently serves as President.