Real-time Image Processing for Portable Devices

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Abstract

An increasing consumer problem concerns the disappointing image quality of many digital prints, and the unavailability of simple, user-friendly remedial procedures. Thus the proportion of pictures printed from those acquired using digital cameras is falling dramatically, and especially from those taken with the newer generations of portable devices. We have previously described the evolution of a real-time image-processing methodology that enables non-technical consumers to optimize their personal images according to individual preference in an entirely intuitive manner. In light of the ability to place this software at any point where a consumer interacts with an image (camera, portable device, scanner, printer, photo-kiosk, desk-top, document processor, etc), we have used the term ubiquitous image processing to encompass all these applied fields. Here we will describe our experiences in applying this user-friendly technology to the latest-generations of touch-screen portable devices, and the technical problems encountered while doing so. These problems have included adapting the image-quality choice hierarchy to the smaller screen sizes, and solving the computational limitations imposed by these devices in order to provide real-time user access to optimum image quality. In addition, it has been necessary to adapt and develop software versions across the gamut of competing operating systems used by these latest touch-screen devices, while at the same time minimizing the application file-size. Practical examples will be demonstrated of fully operational installed versions, including automatic features and a sharpness capability, yet with overall size as installed kept below 100kbs.

Introduction

As the number of consumer digital images escalates by tens of billions each year, an increasing proportion of these images are being acquired using the latest generations of sophisticated mobile devices. The characteristics of the cameras embedded in these devices now yield image-quality outcomes that approach those of the parallel generations of conventional digital cameras, and all aspects of the management and optimization of these vast new image-populations become of utmost importance in providing ultimate consumer satisfaction. However this satisfaction is still limited by the fact that a substantial proportion of all images are perceived to have inadequate image quality, and a lesser proportion of these to be completely unacceptable (for sharing, archiving, printing, etc). These numbers are in the many billions, and the associated economic loss, for example in revenue to the various branches of the digital printing industry, is substantial.

Recently [1 - 3] the author has described various aspects of a consumer digital-image interface based entirely on an intuitive *image-choice-only* operation. Demonstrations have been given of this facility in operation, essentially allowing critical-path navigation through approximately a million possible image-quality states within a matter of seconds. This methodology was made possible by the definition of a set of orthogonal image vectors, and defining all excursions in terms of a fixed linear visual-pixel model, independent of the image attribute. During recent months this methodology has been extended to yield specific user-interactive image-quality solutions in the form of custom software, which at less than 100kb is readily embedded in the latest generations of unlocked portable devices. This has also necessitated the design of new user-interfaces and controls, as well as streamlined and more intuitive versions of the user quality-choice hierarchy.

Technical Development

The challenges of adapting the methodology to portable devices fall within the differing conditions of image display size, available computational power and specific programming languages. An important aspect of these involves the issues of user-judgment of preferred image quality for smaller screen sizes. Figure 1, upper, shows the user-interface as previously developed and described for larger screen sizes, including the use of thumbnails during selection of a specific image attribute. Shown below is a diagrammatic representation of the cascading choice of image attribute (brightness, contrast, color balance), from *coarse*, *medium* to *fine*, where the latter increments of choice correspond to the *just-appreciable visual differences* (JAVDs).

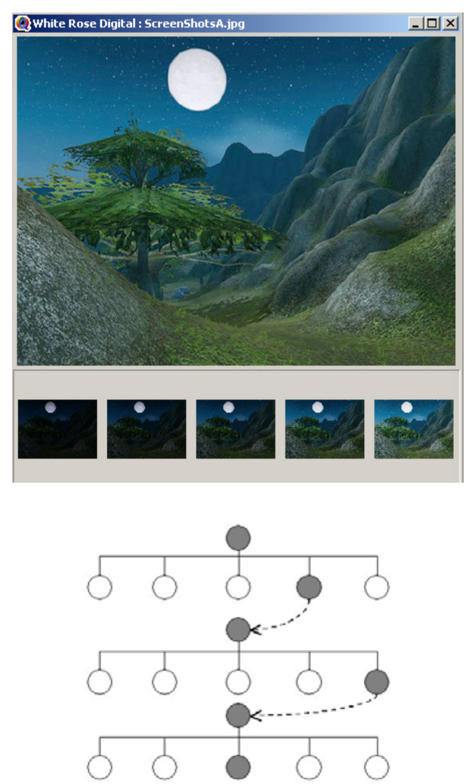

***Figure 1**. Illustration of the original cascading image-choice user hierarchy, based on user choice of thumbnail images.*

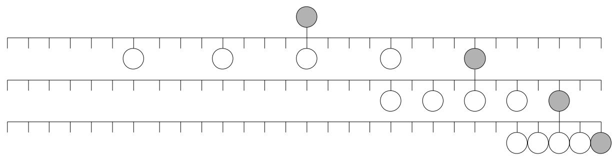

***Figure 2**. Illustration of the practical scale and extent of the JAVDs*

Figure 2 illustrates the scale and extent of the JAVDs, within the thumbnail hierarchy for a specific image attribute. For typical portables with screens in the region of two to four inches, the size limitations imply that the use of thumbnails for user-navigation is not practical, and for convenience even the main image is viewed on a *'maximum central square'* basis, thus optimizing effective viewing magnification independent, for example, of the portrait or landscape image-acquisition mode. The navigation problem was solved by the use of left and right arrows with respect to the original image quality attribute, with the same JAVD intervals and with a similar definition of the practical navigation range for typical camera images, as in Figure 2.

***Figure 3**. Above, the initial user-interface as modified for touch-screen portable devices, based on navigation by arrows while viewing the maximum central square of the image: below, a more sophisticated user-interface where the functional touch-icons are embedded within the full image*

Figure 3 illustrates the evolutionary modifications of the user-interface that were necessary to adapt to a practical portable-screen environment. The upper figure shows the UI as simulated for installation on a two-inch screen unlocked portable device, using a *Symbian* operating system. As subsequently programmed and installed, the entire enhancement package was reduced to a size of less than 90kbs, of which the core enhancement technology occupied only around 20kbs. This package, and associated small file size, included an AI-based set of *one-click-fixes* for brightness, contrast, color and sharpness. As explained previously, such a minimum size is only possible due to our unconventional approach to the core enhancement technology, whereby no formal use is made of standard brightness, tone-reproduction or color-balance theory as such, and these are in effect replaced by a navigating methodology through a million or so pre-determined image-quality states. Even with this advantage, the computations required considerable streamlining and optimization in order to handle the large number of image transformations made on a real-time basis, and the associated complexities of image-management.

The lower figure of Figure 3 shows a PC simulation of the UI developed for the latest generation of three- to four-inch touch-screen portables. For optimum use of screen size the touch icons were embedded within the image itself, and their practical operation reduced to an entirely self-evident basis, as is desirable for any user-friendly interface.

An additional problem that had to be overcome when replacing the thumbnail choice hierarchy with lateral arrow navigation, concerned the details of the color and sharpness scales, with practical details as below.

Color Scale

As an essential feature of the original user-choice hierarchy, we have described the use of visual intervals determined in terms of RGB vectors, enabling rapid and precise user-choice of preferred color balance. For the present purpose it was necessary to modify this approach and to replace it with a single visual scale. After considerable testing with typical users, we replaced the previous color choice hierarchy with a scale whereby the user perceives the navigation as being along a linear *color temperature* scale, ranging from cold to warm, yet with visual intervals still set in terms of the same basic JAVDs.

***Figure 4**. Thumbnail illustration of the new single linear color scale, as adapted for lateral arrow navigation*

Sharpness Scale

The implementation of a user-choice sharpness facility on a small-screen portable-device poses especially challenging technical hurdles, both of judgment and computational complexity. The original thumbnail display, plus hierarchical choice, also had to be replaced by a lateral navigation facility, with intervals at JAVDs. Unlike the core features of brightness, contrast and color balance, sharpness falls within the classification of pixel-conditional algorithms. In fact for this new requirement a new algorithm was devised and constructed that was both strictly linear in the visual sense, and yet at the same time considerably less demanding in computation.

Figure 5*. Thumbnail illustration of the new visually- linear sharpness scale, as adapted for lateral arrow navigation*

Figure 6*. Detail of original and sharpened image, with latter as chosen by user along a linear sharpness scale, using the enlargement of a key image feature*

The new sharpness algorithm was first installed and tested using the original thumbnail choice hierarchy, as in Figure 5. Following user-validation it was then implemented on a portable device with navigation via left and right navigation arrows. The choice problem was addressed by the inclusion of a user-defined enlarged image area for the judgment and control of the required degree of sharpness, as illustrated in Figure 6. This allowed optimum sharpening for images as perceived on PC screen or print, when subsequently utilized (shared, printed, archived, etc) at sizes in the region of four to seven inches, as typical for consumer use of phone-camera images.

Automatic Enhancement

The basic properties of the enhancement methodology make it ideal for the application of artificial intelligence (AI), from the viewpoint of developing entirely automatic versions. The absolute nature and reversibility of each interval in the manual enhancement process procedure, and the recording of each individual step for many typical test images, have provided a large amount of data, which in turn has been used to devise automatic procedures based only on the incoming image statistics. There is however a fundamental philosophical issue of the exact nature and reliability of outcome for such automatic procedures. At this stage we have opted for an intuitive set of corrections that can readily be undone and replaced by manual control. In general our approach classifies images according to whether they are too light or dark, or the contrast is too high or too low, and corrects them appropriately, with generally satisfactory results and low failure rates.

Auto versions for color and sharpness are more problematic. However we have produced an auto-sharp feature based on a conservative number of navigation steps that produce a pleasing outcome in the majority of user trials. Images requiring subtle changes in color balance are among the most difficult to correct automatically. However the provision of an *'auto-cool'* and *'auto-warm'* color-balance facility has been found to provide significant user satisfaction so far as the fine-tuning of flesh tones are concerned, the latter typically being the most critical facet of user judgment of overall image quality. An example of the simple and rapid choice they offer to the user is shown in Figure 7.

Figure 7*. Illustration of range of color auto features: middle; original image; top; auto-cool version; bottom; auto-warm version.*

Practical Testing

User-testing via a large number of practical and typical phone-camera images has been carried out in recent months, and the conclusion is that the ability for the non-technical consumer to successfully enhance images to personal preference is equal to that previously found in our practical studies for larger-screen devices with greater computer power. In fact the practical conclusions from this portable-device application have led to useful modifications and improvements of our existing PC user-interface as developed for generic digital enhancement purposes on larger screens and displays.

***Figure 8**. A phone-camera image taken at late dusk: above, original image and below, as enhanced.*

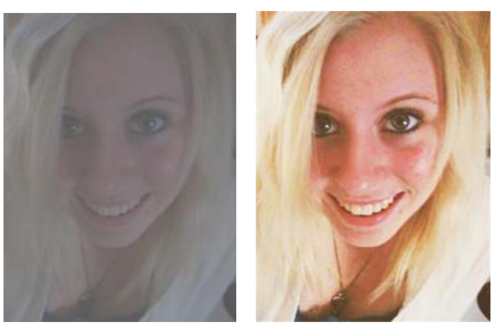

***Figure 9**. Image requiring major enhancement of both contrast and color*

Figure 8 shows an image as acquired at dusk, that otherwise would have been discarded by the user. This was obtained using manual choice of brightness enhancement at near the maximum increment on the linear-visual scale. It should be noted that the corresponding auto-fix approximated this same degree of brightness enhancement. In this extreme case the enhancement feature has essentially turned the camera into a night-vision device, limited only by the intrinsic photon-noise-limited nature of the original scene. An example is shown in Figure 9 of an image where major enhancements of both contrast and color were necessary in order to obtain acceptable reproduction.

***Figure 10**. Before and after images of a typical scene acquired under gloomy lighting conditions, and enhanced to full tone and color reproduction.*

Figure 10 shows a before-and-after comparison of a more typical cell-phone image needing simultaneous enhancements of contrast and color, in addition to brightness. The enhancement operation has produced an acceptable image having full tone and color reproduction from an original scene representative of the gloomy conditions under which it was acquired.

Summary and Conclusions

A basic set of image enhancement procedures have been modified for the specific environment of portable devices, where smaller screen sizes and less computing power involve additional challenges. This has necessitated the design of new user-interfaces and controls, as well as streamlined and more intuitive versions of the image-choice hierarchy. The technical modification and details of the modified user-interface have been described, and practical results shown for a complete enhancement package having both manual and automatic features, as installed in on a typical portable device.

References

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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, a provider of consumer digital-imaging solutions, where he currently serves as President.