

# Ubiquitous Image Processing: A Novel Image-Enhancement Facility for Consumers

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## ABSTRACT

Image-enhancement technology has been developed from first principles whereby an unskilled user may enhance and optimize the image quality of any digital photograph to personal choice within a matter of seconds. The novel methodology, which by virtue of its simple user-interface, real-time computation, and lack of any appreciable user learning-curve, naturally lends itself to many practical imaging applications in addition to that of a stand-alone application, including digital cameras, printers and photo-kiosks, or provision as an image-processing web-service. The basic imaging philosophy and principles leading to the development of this enhancement technology are discussed.

## 1. INTRODUCTION

### 1. 1 Background

While the number of photographs taken using digital cameras is still growing exponentially, with annual growth rates measured in the tens of billions, experience shows that more than fifty-per-cent of all acquired pictures could be significantly enhanced for increased consumer satisfaction. A similar conclusion applies to the countless scanned prints, negatives and slides, etc, that are now an integral part of the consumer digital world, and to the myriad images available for viewing on the web. Thus, while the market potential for user-friendly image-enhancement software is huge, typically the majority of existing image-enhancement software is either over-simplistic, user-hostile, or both, as well as being limited in effect.

Broadly speaking, consumer image-enhancement tends to fall into two main categories. The first of these consists of the comprehensive menu-approach, as used in the more substantial imaging-software packages that are currently available. These typically collect together a number of statistical-functions, digital-descriptors, analog-photography concepts, etc, and then attempt to provide some degree of control to the user for some or all of these. Such menu-based methodologies inevitably have their inherent advantages and drawbacks. The controls provided are usually non-independent, often have no implicit preferential order of use (even though they are generally non-commutable), and while an experienced and knowledgeable user may apply these powerful software programs to great benefit, the steepness of the learning-curve is generally prohibitive to the average consumer. An alternative approach, growing in commercial popularity but often of very limited effect, is the use of fully- or semi-automatic image-enhancement tools, usually based on specific algorithms that operate on anticipated defects existing in certain classes of digital imagery. While in some limited cases and for certain image-types, these may provide remarkable and satisfying results, all tend to contravene to some degree the important principle of 'first do no harm', and are thus usually and necessarily provided with the means to undo their influence and revert to the original image. One of the authors has previously described his own versions of some of these, including a procedure for enhancing image sharpness<sup>1</sup> and one providing a remedy for some types of extended latitude images<sup>2</sup>.

As a result of the present practical status, the vast proportion of consumer digital-images remain aloof from image-enhancement methodologies of any description, even though a large fraction of them would naturally lend themselves to immediate perceived improvement and appreciation by the consumer. In some imaging applications this may be relatively unimportant, but experience shows that optimum image-quality is paramount for all the traditional drivers of picture-taking, as now translated into the new digital domain. Pictures of weddings, babies, graduations, and other such special life-events are of prominent concern to the consumer, and if readily available, appropriate image enhancement would be an important value-added proposition. Further our own field experience shows that from among the general gamut of modern digital-imagery, typified by pictorial web-sites and blogs, a substantial fraction of all users would welcome simple image-enhancement of their pictures, and this generally increased consumer satisfaction would be to the greater benefit of the imaging industry as a whole.

## 1. 2 A Novel Approach to Consumer Image Enhancement

In view of the above practical reality, there is an obvious and urgent need to provide the typical consumer of digital-imagery with a simple image-enhancement methodology. This methodology should embrace all the enhancement benefits of the more sophisticated photo-software programs whereby the users retain control and by principle choose the enhanced version of the image entirely to their own personal criteria. At the same time, the procedure should have the simplicity of use associated with the typical existing algorithmic ‘try-this’ one-click fixes. The question then becomes one of feasibility of combining the benefits of these approaches while introducing none of the drawbacks.

Over recent months we have developed a novel methodology that meets these and other important practical criteria. The resulting software, which by virtue of its simple user-interface, real-time computation, and lack of any appreciable user learning-curve, naturally lends itself to many practical imaging applications in addition to that of a stand-alone application, including digital cameras, printers and photo-kiosks, or provision as an image-processing web-service. The basic imaging philosophy and principles leading to the development of this image-enhancement methodology are described below.

## 2. CONSUMER IMAGE ENHANCEMENT

### 2. 1 Which Image Enhancement?

In view of the wide usage of loosely defined terms covering the general topic of image-enhancement, it is appropriate to give a precise definition of what this term denotes within the present context. Other terms such as image-processing are often used as synonyms, along with those such as image-restoration and image-manipulation, and catch-all phrases such as photo-editing are now widely used in the an ever-growing modern circle of consumer digital-imaging. But all these and other common terms are frequently used interchangeably, and mean quite different things in different contexts. For the present purposes we define image-enhancement, in the sense used here, with the help of Figure 1.

Due to common usage, it is first necessary to separate out those common and already well-served and widespread image-manipulations that may be thought of as falling under the general heading of digital ‘good-housekeeping’. These include the ability to change the size and format of the image, to crop and rotate the image to choice, to compress the image for digital transmission, etc. Perhaps curiously at first sight, we include here for convenience what is actually an advanced topic of image-segmentation, namely that of red-eye reduction and removal, since due to shrinking digital camera sizes and optics this problem has revisited the world of photography in its new digital guise, and in some imaging software packages this is actually the dominant remedial component.

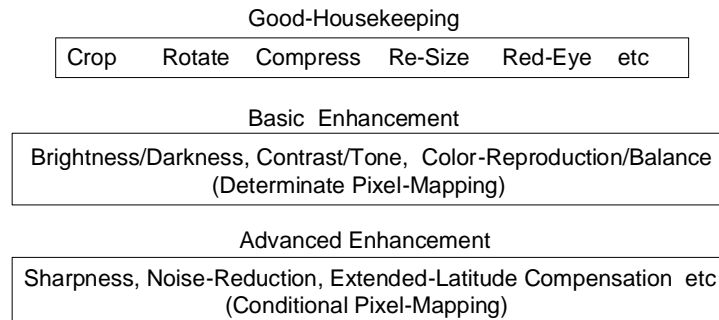


Figure 1. Classification of image-enhancement activities and manipulations

Under the heading of basic enhancement in Figure 1, we include all those image attributes that may be thought of as the digital surrogates in the translation from classical analog tone- and color- reproduction theory. These represent all aspects of the image relationship to the original scene in terms of its perceived brightness across all regions of the image, likewise the color reproduction, and the tone or contrast associated with each brightness region of the image. This area of image enhancement that we label here as ‘basic’ now has the special further assumed property whereby all image manipulations within this domain are obtained within the rule of determinate pixel mapping. In other words, only enhancements are assumed permissible which operate in a predetermined manner on each pixel, independent of the state of any adjoining pixel, or groups of pixels.

In the latter context, all those image enhancements that operate conditionally on pixels depending on the state of defined regions of adjoining pixels are gathered together in the third area of Figure 1, under the heading of advanced image enhancement. In addition to many of the ‘single-button’ consumer facilities, this class of techniques includes such well-established image processing methodologies as those used for increasing sharpness or reducing noise, as well as a current slew of approaches to the so-called extended-latitude problem whereby very wide ranges of brightness levels in the original scene must be represented in satisfactory manner within a defined image pixel range.

According to the classification of these latter techniques as ‘advanced’, it might seem that they might be anticipated to produce the most beneficial results, but our experience shows that this is not usually the case. The simple reason behind this statement lies in the observation that it is usually preferable to first exhaust all attempts at enhancing the image using the basic set of methodologies prior to even attempting the advanced set, for the reason already given, namely that the majority of advanced techniques by definition introduce their own unwanted image defects. Thus the use of advanced enhancement may become a balancing act between desirable image improvements and the addition of new undesirable image artifacts. Examples of these artifacts include image-contouring, haloes and ringing effects, color spills into adjacent image regions, and all other outcomes of the algorithmic footprints on the image that are implicit in all conditional pixel-mapping methodologies.

The practical reason why the basic set of image enhancement methodologies are not attempted first, and only augmented later by advanced methodologies if and when necessary, lies in the simple reality that there is no obvious systematic way of doing so. However, by consideration of the determinate pixel-mapping basis, so long as the pixel-mapping procedures obey certain obvious rules (continuous, single-valued, well-behaved at the extremities of the pixel range) they are relatively free from the introduction of unwanted image-defects of their own. The novel enhancement methodology described here is based on this premise, and the key element of the procedure lies in a systematic exploration of the entire basic image-space of brightness/darkness, contrast/tone and color reproduction. As we shall argue based on our own practical experience, when this basic image-space has been explored in this manner, then in fact the perceived need for augmentation by advanced enhancements is reduced by such a significant amount that typically the consumer is entirely satisfied with the image quality in the absence of any additional advanced image-quality enhancements. Only a much smaller fraction of all consumer images are then deemed to need advanced techniques for, say, image-sharpening or extended-latitude imagery.

## **2. 2 Existing Consumer Enhancement Methodologies**

It is appropriate at this stage to give a brief survey and set of examples of some of the facilities most commonly used in readily-available consumer digital software.

Adobe Photoshop remains prominent in the field, used by a substantial fraction of all digital-imaging professionals<sup>3</sup>. Among provided manipulations and controls that fall within the present classification of basic image enhancement, are those of pixel-levels (access to the histogram showing the statistical distribution of pixels over the entire range) and means for mapping these levels as desired. The latter mapping may also be attempted in simpler form by use of auto-levels and auto-contrast buttons. Color balance may be manipulated by use of sliders for separate R to C, G to M, and B to Y shifts. In addition to these controls there are separate controls in the form of user-interactive sliders spanning brightness, contrast, hue, saturation and lightness. Experience shows that personal recipes may be derived from persistent use of these controls, yielding the ability to carry out entirely satisfactory enhancements of consumer pictures, at the expense of a steep learning curve and a time-consuming enhancement procedure for each separate digital image. Recent simpler consumer versions of the Adobe flagship software, such as Adobe Photoshop Elements, attempt with some success to reduce the learning-curve and provide a simpler user interface and set of enhancement controls. Among a host of software programs offering similar digital enhancement facilities, those provided by Corel<sup>4</sup>, with Paint Shop Pro and Roxio<sup>5</sup>, with PhotoSuite, are in widespread use, again mainly among the serious enthusiast or professional category of user.

Recently, photo-enhancement facilities provide by major web-based companies have had great publicity and gained a dedicated following. Prominent among these is Picasa, an application provided by Google<sup>6</sup>. In addition to some of the usual good-house-keeping functions and within the basic enhancement category as defined here, single-click buttons labeled Auto Contrast and Auto Color are augmented by a slider for Fill Light (increase of image brightness) and a button labeled ‘I’m Feeling in Lucky’. Experience shows that the very minor excursions into image-quality space provided by these latter facilities are to some extent offset by extreme simplicity of use, no doubt why this is such a popular photo-enhancement site. Similar simple procedures are provided by lesser-know web-names involved with picture sharing and editing, including OurPictures<sup>7</sup>, among many others.

Many available software algorithms, consumer programs and web-sites exist that appear to exploit the best concepts of advanced image enhancement, based essentially on conditional pixel mapping. Those based on the well-known Retinex concept<sup>8</sup> are dominant among these, and NASA/Langley has, among others, been a prominent developer of this concept, with demonstrations of typical before and after images<sup>9</sup>. While remarkable results may often be obtained by informed use of this concept, the best results appear to be provided when a series of parametric controls are used rather than a single-button application, moving this even further away from a simple consumer operation, and there is always the implicit problem of stronger enhancements introducing new and unwanted image artifacts. Among other consumer providers Ulead, with its Photo Impact software, shows a before-and-after gallery, and stresses its enhancement capabilities for high-dynamic range images<sup>10</sup>. Athentech Imaging, with its Perfectly Clear enhancement technology, shows a web-gallery of images apparently based on a single-button operation, appearing to be based on conditional pixel mapping techniques<sup>11</sup>. Human Software provides a variety of plug-ins for Adobe Photoshop, including techniques for Autocorrect, with details such as Rebuild Color & Image Detail, with pictorial examples provided on its web-page<sup>12</sup>. Finally, from among many other web-providers, a procedure based on a novel use of neural nets is due to Logical Designs Consulting, again with practical illustrations provided on its web-pages.

### **3. A NOVEL APPROACH TO CONSUMER IMAGE ENHANCEMENT**

#### **3. 1 The Fundamental Challenge**

This present contribution addresses the fundamental challenge of providing the consumer with a simply methodology whereby the image may be rapidly and uniquely positioned in the optimum region of the basic available image quality space, as previously discussed, and as illustrated by the middle segment of Figure 1. In view of the very large number of combinatorial pixel-mapping functions that might be chosen as surrogates for the basic imaging concepts of brightness/darkness, tone/contrast and color-reproduction and balance, this may seem a formidable challenge, yet a closer inspection of the problem gives reason for hope. In fact in the absence of any knowledge of image attributes, any digital photograph has only around five or six fundamental and independent variables, as seen from a strictly physical viewpoint. An entirely physical viewpoint, free from any imaging culture, would thus start by defining any captured digital image as a statistical ensemble, for example as encountered in statistical mechanics, where concepts such the partition function might be used to render the large number of possible combinatorial states of the fundamental variables into a consistent and tractable calculus. If correctly defined and placed, for example, within an information-theoretic-type framework, these variables can form the basis of a robust image-quality choice hierarchy. However this also calls for translating the variables into a realistic set of image attributes. Even if and when this can be carried out in a practical manner, the question remains of the range and linearity of the scales associated with these variables, and, most important of all, that changes in the physical variables to which they relate correlate directly to the visual impression in the perceived image.

#### **3. 2 Basic Steps to a Practical Solution**

The essential steps towards a practical solution that includes all the above observations might be summarized as follow:

- Define a basic and image-appropriate set of individual physical variables representing any digital image
- Order these independent variables within an overall logical hierarchy
- Define the practical range of these variables for a comprehensive consumer image set
- Set the interval scales within these ranges in terms of linear visual effect
- Determine the just-appreciable visual differences within these scales for the same typical consumer image-set
- Ensure that the full operation of these variables introduces a negligible degree of associated image artifacts
- Calculate the total number of combinatorial image states in the image
- Provide consumer-access to each of these image states using a critical choice hierarchy

At first sight this might appear to be an ambitious task, unlikely to lead to any practical consumer-friendly solution. However by breaking down the essentials steps into a well-defined sub-set, as above, and by addressing each of these individually and then collectively, we were able to arrive at an entirely practical solution, as will now be described.

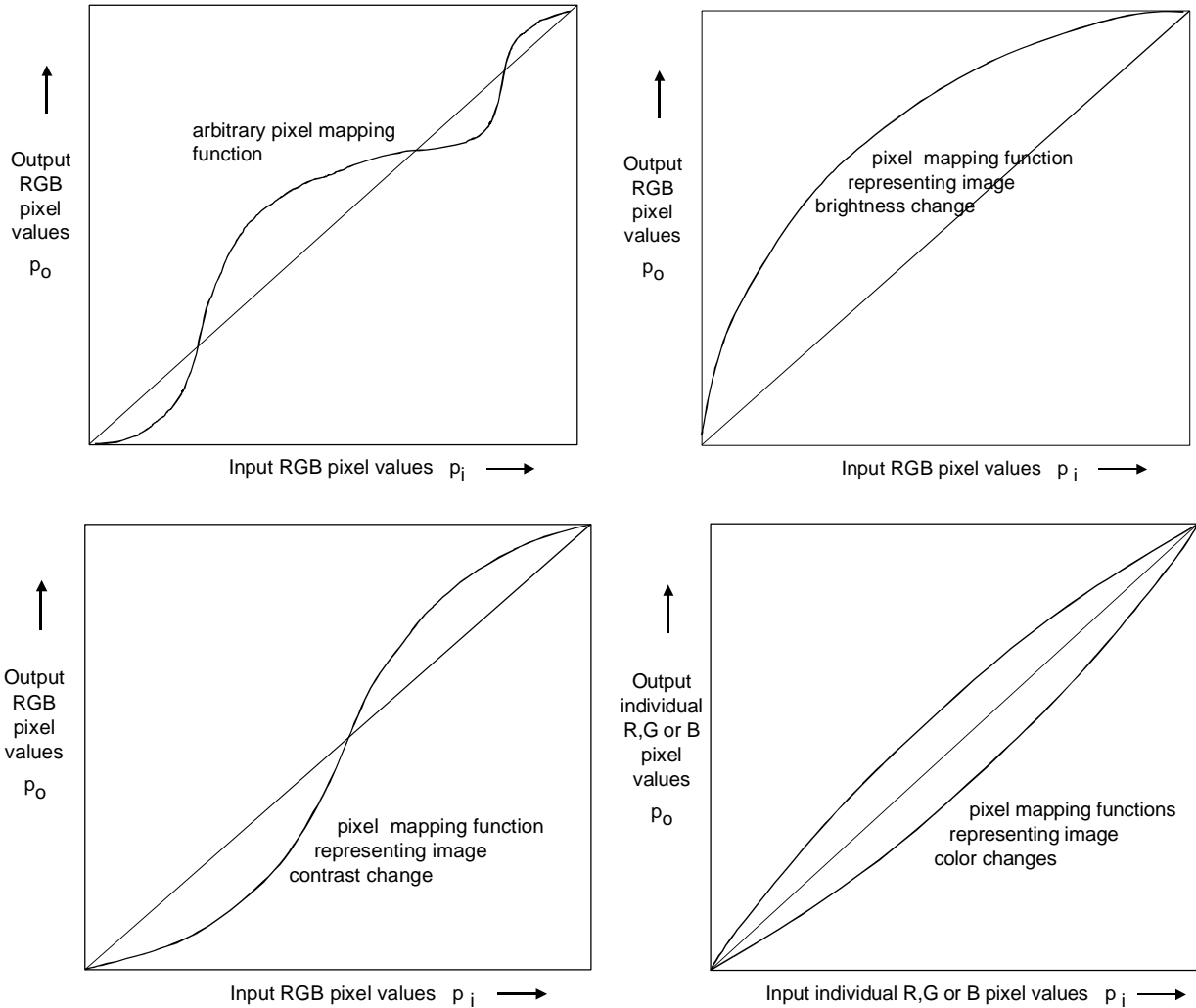


Figure 2. (above left) Illustration of an arbitrary pixel-mapping function ; (above right) Surrogate for image brightness/darkness; (lower left) Surrogate for image contrast/latitude; (lower right) Surrogate for changes in individual RGB color balance.

#### 4. BASIC IMAGE ENHANCEMENT METHODOLOGY

##### 4.1 The Practical Physical Variables

We make the fundamental assumption that the essential physical variables to be used in the basic enhancement methodology can all be determined by unique operations on the basic pixel-distribution representing the digital image, and that such operations are ‘well-behaved’ (continuous, single-valued, cover the entire pixel-range, are rational at the pixel-extremities etc). Figure 2 (top left) shows an arbitrary pixel-mapping function, obeying these rules, but having little or no systematic image-enhancement significance. Three further specific and image-significant examples of pixel-maps are shown in Figure 2, representing the three chosen modes of image variable. As illustrated at top right, the first mode of pixel-mapping represents a systematic change of the image brightness level. As shown, this yields a systematic defined enhancement of brightness in the image, while the mirror-image of this function naturally represents a corresponding systematic enhancement of image darkness. As illustrated at bottom left, the second mode of pixel-mapping represents a tone-manipulation of the image, whereby mid-tones (mid pixel regions) are associated with increased gain (contrast), at the expense of decreased gain in the shadows and highlights (low and high pixel regions). In this case the mirror image of the curve as shown represents the inverse effect on the contrast associated with these pixel regions. Finally, as illustrated at bottom right, the individual pixel color (RGB) components are operated on in the above brightness/darkness sense using a similar pixel-mapping function.

Having classified the pixel-mapping variables into three basic modes in this elementary manner, we then make the further assumption that these modes may be optimally combined as a linear sequence of ordered operations, starting with brightness/darkness, continuing to contrast/tone-reproduction, and finally addressing color-balance/reproduction, and in this sense constitute a sequence from the largest to the smallest changes in typical images. Hence this sequence comes as close as is practically feasible to representing an independent set of enhancement variables. Our experience with a very large number of consumer images shows that assumption is entirely satisfactory from a practical viewpoint. A flow-chart summarizing the operation of these basic variables is shown in Figure 3.

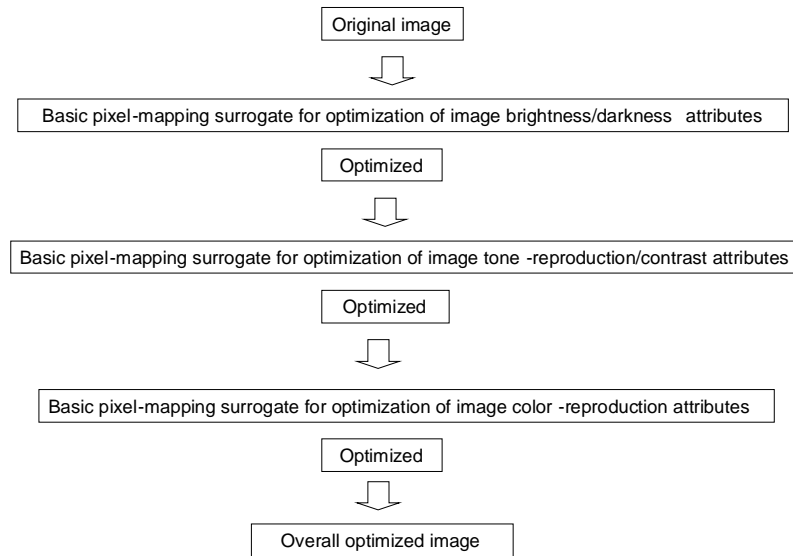


Figure 3. Schematic of a strategy for sequential optimization of image attributes

## 4.2 The Practical Ranges and Intervals of the Variables

With the pixel-mapping variables established in terms of the corresponding image properties, the problem remains of determining the practical range of each variable, and defining the minimum interval within this range that corresponds to a user-significant difference for each specific image-variable. In establishing these, it is essential that they relate directly and linearly to the consumer visual experience, and especially that the intervals within the practical ranges are defined in fixed intervals of visual response. These ranges and basic intervals were determined from practical digital-image statistics taken by viewing and enhancing several thousand typical consumer pictures, spanning all types of possible image-source, and covering the range from lowest to highest image quality imagery.

The somewhat surprising conclusion of these practical studies was that, as a rule of thumb and within the assumptions of visual linearity, the number of discrete image-states for each attribute could typically be reduced to around thirty. In other words, thirty distinct image-states, correlated with thirty distinct pixel-mapping variations of the assumed basic brightness/lightness surrogate, covered the entire practically established-range, and thereby accommodated more than ninety-nine percent of all consumer images. A similar conclusion was reached for the pixel-mapping function associated with contrast/tone-reproduction, and likewise for color balance and reproduction, although in the latter case, for example for badly faded scanned negatives whose color balance have shifted drastically over the decades, a significantly increased gamut of accessible image color states may occasionally be appropriate.

Based on these approximate numbers, the problem associated with a basic enhancement choice-hierarchy becomes immediately obvious. Assuming that a number around thirty is appropriate for each of the sequential choices, and that the image-states are independent and combinatorial, the conclusion is reached that there are around  $30^3$ , or 27,000 overall distinct image-states. More exact and complex calculations and studies have shown that while in fact a much greater number of different images states (perhaps in excess of  $10^6$ ) would be necessary to cover more strictly the most complete consumer experience of overall image quality, nevertheless, the lesser number estimated above would serve to satisfy the overwhelming majority of user image-choice outcomes

### 4.3 Defining the Hierarchy of User Choices

Even with this lesser number of image-choices, the practical problem of presenting each of individual choice to the consumer and inviting individual selection according to personal perception, would at first sight seem an insurmountable one. This would seem especially to be the case in light of the further practical aim of making the choice simpler and more intuitive than in existing comprehensive software packages, to do so without the necessity of setting variables, adjusting curves or moving sliders, etc, and to develop a procedure such that with the minimum of training an inexperienced and non-technical consumer could make this selection with negligible ambiguity and maximum ease within a few seconds.

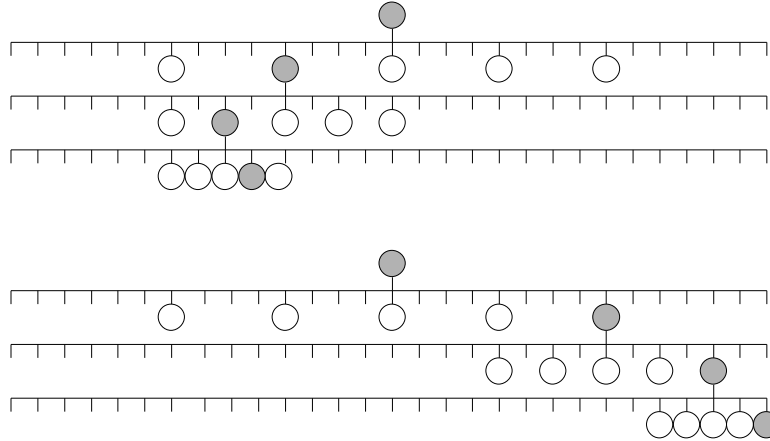


Figure 4. Illustration of image-choice methodologies, based on five-at-time hierarchy: (above) typical decision-tree ; (below) showing how extremes of the range may be selected.

Figure 4 shows a schematic illustration of the principles used in devising an optimum image choice hierarchy. For a given attribute, say brightness, the practical number of distinct brightness states is represented by equally-spaced increments in visual space. Initially five states are presented to the user, including the original. Choice of one of these (solid-gray) leads to a further set of brightness states being presented to the user. As illustrated, three such choices allow for total exploration of the entire range, even though in the top example only eight image brightness states have been presented to the user along with the original. In the lower example of Figure 4, a critical choice path is shown that allows the user to navigate to the extreme of the practical range of states for this particular image variable.

An entirely analogous choice-hierarchy as that of Figure 4 is used for the subsequent choice of independent contrast states, and likewise for color, although for the latter states a slightly modified approach is used in view of the typical desire to explore independently the three basic color (RGB) states.

By use of this sequential image-decision-tree, substantial experience has shown that a total of ten image-clicks represents the typical user selection process, and that following superficial user-familiarity with the entirely intuitive choice procedure, a single digital picture may be enhanced to individual image-quality choice by an average consumer in around fifteen seconds.

## 5. OVERALL OPERATION AND PRACTICAL RESULTS

### 5.1 Translation into Basic Enhancement Software

Having established the basic physical variables, their surrogates in imaging-space, the practical ranges and intervals in linear visual-space, and having then placed the entire image-quality space within a critical choice hierarchy, it remains to translate all these operations into a unified and user-friendly software package. The main ingredient making this possible is the assumption of the simplest form of the underlying pixel-mapping functions, as exemplified in Figure 3. This has meant that real-time calculations can readily be made corresponding to each image variable, and recalculation and representation of the next image choices can be made almost simultaneously.

The user-interface associated with the software continues to undergo modifications and improvements aimed at consumer simplicity. Comparisons and choices are typically made using a mouse-sweep and click over a five-at-a-time thumbnail image-set, with the main image always representing the latest stage of the overall selection procedure. A facility is also incorporated for immediate comparison of this latest image with the original, from start to finish. For rare

images requiring substantial and simultaneous changes in each of the brightness, contrast and color states of the image, there is the ability to return and recycle through any previous stage. Additions to facilitate the user-experience, further reduce the initial learning-curve, and decrease the procedural time are being continually introduced as part of a natural development program. Also other user-interfaces are being developed, as appropriate. For example, a quite different interface might be appropriate for a touch-screen photo-kiosk application, rather than one in a software package sitting on a computer desk-top.

## **5.2 Practical User Experience**

To date several thousand consumer digital images have been enhanced using this new simple procedure, and a small control group of typical users have sampled the software and applied it to their own collection of digital images, mainly but not limited to those images acquired using modern digital cameras. A large number of statistics and general observations have been gathered from this exercise, and these are being used as the basis for future fine-tuning of the software operation and the user-interface.

Some of the initial observations have at first sight been surprising. The original premise for the design and development of this software was primarily that of a rescue operation for the significant number of digital images suffering from any number of a common set of image-acquisition failures. These include scanning failures based on both the scan operation itself not being satisfactorily optimized, or operating on faded, blurred and grainy originals; also digital camera failures such as results sub-optimum image-lighting or imperfect camera color sensors. However practical experience soon confirms that a small but significant sub-set of such images is beyond redemption using basic enhancement procedures of any description. The main features of this sub-set of images are typically classified by low resolution or high noise, or both, and especially by extreme compression during prior transmission to the point of use.

This class of problematic consumer imagery parallels those found in applied fields as for example typified by medical diagnostics, forensic and satellite/reconnaissance imaging. In these specialist non-consumer fields, there is a considerable activity in developing advanced image processing techniques. While in due course these might be successfully applied in the consumer domain, at this time practical considerations concerning computation time, cost and complexity are unlikely to make this a practical proposition, and fall at the other extreme of the intent of the basic enhancement software described here. However, even for these images, as for all others tested in our field-studies, no additional significant artifacts or reductions in image-quality have been observed attributable to the image enhancement software itself.

While these natural limitations for any consumer enhancement software, our experience is that there are major offsetting surprises in the ever-growing class of high quality consumer imagery as sophisticated high-mega-pixel digital cameras proliferate. In fact, on reflection this should be no surprise, since using the very logic and principles described above, and which form the basis of our own enhancement software, these more sophisticated image-capture devices will acquire images having the highest signal-to-noise ratio, degrees of freedom, etc, which in our terms we think of as potential independent image-quality states available for exploration. At the same time, the probability that the collective acquisition technology (hardware and software) associated with these camera will place the image in the optimum available image quality state from among the many options is increasingly remote. Thus the implications are that these high-resolution digital-capture devices present a capability for image enhancement not present with less sophisticated devices, and this has been our own experience. A large number of image-states (as estimated above and measured in hundreds of thousands) are readily available for exploration, and typically unlimited by resolution-defects or film-grain. From among the field studies already conducted, this higher class of digital images has resulted in some of the most pleasing enhancements.

As a test basis, such high-class digital imagery can naturally be found and downloaded from web-pages associated with the obvious image-quality brand names such as Eastman-Kodak<sup>14</sup> and National Geographic<sup>15</sup>, or in superior digital web-collections such the Friedman archives<sup>16</sup>. Our own test enhancement of already very high quality digital images has provided a satisfying learning experience in this respect. In effect, the freedom to explore all the alternative available image-quality states leads to a personal selection for each image that may be well displaced from the original, and due to this individual choice can transform an already outstanding image into one of ultimate user-satisfaction.

## **5.3 Image Enhancement Gallery**

A large set of samples of typical before-and-after images has been collected from these initial applications of the software. By definition none of these can be reproduced here in any meaningful way, and thus no attempt will be made to do so. Selective sets of these images, representing a wide category of consumer interests and imaging-capabilities spanning all quality levels, can be seen at our web-page<sup>17</sup>. But even these miss the point of the central thesis presented

here, namely that the technology, methodology and associated software were developed to exist at every convenient point of consumer access (camera, scanner, printer, computer, photo-kiosk, etc), and that the only meaningful before-and-after comparisons are those made on images enhanced by the actual consumer in the context of the viewing conditions at their own particular point-of-access to the image.

## 6. SUMMARY AND CONCLUSIONS

We have described the concepts and operating principles of a practical novel image-enhancement methodology designed specifically for technically unsophisticated consumers. The associated software is intended for distributed use at any point where the consumer interacts with a digital image, whether in camera, printer, scanner, computer screen, photo-kiosk, or embedded in graphical word-processing software, etc. However it is also ideally suited for central point-of-service applications, exemplified by larger-scale digital printing facilities or central web-based image-enhancement services. The extreme simplicity of use enables instant consumer familiarity without the usual frustrations of a steep learning-curve and complexity of operation.

The imaging theory used as the basis of this methodology has been reduced to the most elementary form, and translated into a primitive set of pixel-mapping equations representing brightness/darkness, contrast/tone, plus color reproduction and balance. In effect the resulting methodology allows the consumer to choose between many thousands of potential image-quality states based entirely on personal preference, and to do so without ambiguity in a matter of seconds. These image quality states are pre-determined by the establishment of calibrated visual ranges and linear visual intervals. Due to the nature of the pixel-mapping equations, minimal image artifacts are introduced during the process. The comprehensive nature of the image-quality space available for exploration means that many previous separate image-enhancement algorithms are implicitly included within this new single enhancement methodology.

Future versions of this software will apply the same methodology of simple consumer visual choice to advanced image-enhancement attributes, including those for enhancing sharpness, noise reduction, and dealing with a special class of extended-latitude imagery, and in due course will be reported at future conferences in this series.

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