A Two-dimensional Adjustment Tool for Color Image Enhancement

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Abstract

One- and two-dimensional adjustment tools were tested to find ways to make the enhancement of photographic color images as easy and quickly as possible.

Visually assessed image quality was defined as a function of two global image properties for various test images. The emphasis was on the brightness/contrast combination. Results showed that the location of the maximum and the shape of these (two-dimensional) quality functions varied considerably from image to image. Moreover, in many cases it proved to be difficult to attain optimum quality when image properties were adjusted separately. Often several additional iteration rounds (i.e. repetitive back and forth movement of the two sliders) were needed. To avoid this, a two-dimensional adjustment tool was developed. This tool gives the user real-time visual feedback and an opportunity to adjust two selected variables simultaneously simply by using a mouse to move a cursor on a two-dimensional plane.

Two-dimensional image adjustment proved to be more efficient (i.e. faster) than two one-dimensional adjustments. Tests with brightness/contrast adjustment showed that 2-D adjustment is much quicker when the original adjustment variables are far from their optimum values and when the test person is well-trained. If the person is not well-trained, two-dimensional adjustment should be combined with automatic guidance.

Introduction

There are many different interactive tools for color image enhancement. For reasons of efficiency, these tools often change image colors globally. For example sliders are commonly used to adjust contrast, saturation, brightness, color balance and other image properties. When several global adjustments are made successively one at a time, it may be difficult to find the optimal combination, because it is often very difficult to predict how the adjusted image properties affect each other and the overall image quality. The goal of this study is find ways to improve interactive image enhancement by adjusting two different image properties simultaneously. In practice, this is done by moving a cursor with a mouse on a two-dimensional plane where the horizontal and the vertical locations correspond to the values of the two adjustment variables. For practical reasons, especially considering that real-time visual feedback is required, the adjustment algorithms must be relatively simple. In this study, the adjustments were carried out by changing the color components of RGB images by means of simple tone rendering curves.

A Single Two-dimensional vs. Two One-dimensional Adjustments

If we compare two one-dimensional (1-D) adjustments tools with one two-dimensional (2-D) tool, in principle the latter cannot be less efficient because it can always be used like two separate sliders (horizontal and vertical). Moreover, 2-D user interfaces are more flexible and intuitive. This does not mean that two-dimensional adjustment would necessarily be easier or quicker to use than traditional 1-D adjustment tools. If, however, the user knows the optimum combination of the two adjustment variables exactly or at least with sufficient accuracy, the benefits of 2-D adjustment tools are easy to prove.

On a 2-D plane a cursor can be moved with a mouse to the desired location in about the same time as a 1-D slider. If done carefully, this takes about four seconds (including the time needed for moving the cursor to the appropriate starting point). When two sliders are used this must be done twice. Thus there are about four seconds per image to be saved, although in practical interactive image manipulation this is hardly essential.

Adjustment of Brightness and Contrast

In practice, the user of any image enhancement software seldom knows exactly (quantitatively) what adjustments are needed. As a rule, interactive image manipulation implies selection and twiddling of different adjustments on the basis of constant visual feedback. In theory, it might be beneficial to make more than two adjustments simultaneously, but this seems impractical in terms of the user interface.

Efficient image enhancement implies that the primary visual effect of every adjustment made is distinguishable from all other adjustments. In practice, however, it is very difficult to control how different adjustments affect each other and overall image quality. Attaining the best possible results would be easy if image quality had a clear maximum as a function of the adjustment variables, as illustrated in Fig. 1. This function should also retain its shape regardless of all other adjustments made. It cannot be assumed that this is true for any global color adjustment. Some adjustments are, however, more independent than others.

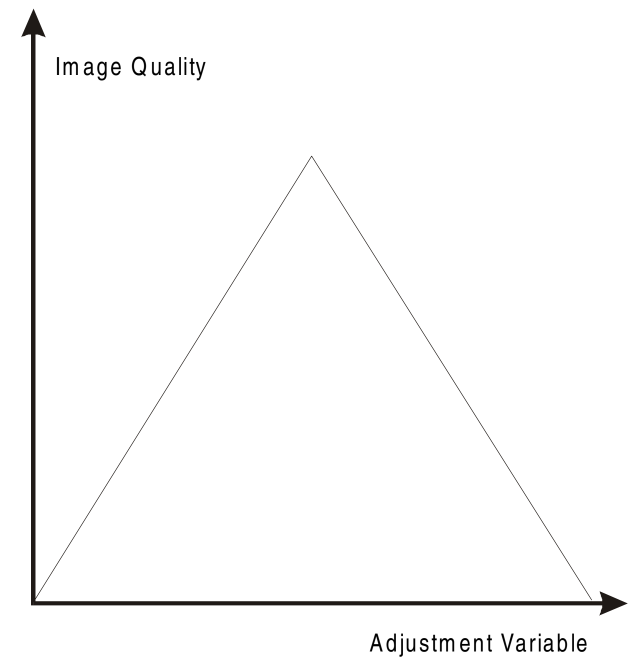

Figure 1. Simple "optimum" quality function

2-D image manipulation tools can best be utilized combining two adjustments whose effect on image quality depends on that of the other. Also these adjustments must be simple, relevant and constantly needed in practical image enhancement. After brief preliminary tests of various image properties, brightness and contrast were selected for further testing. Brightness adjustment was carried out simply by adding positive or negative RGB tonal values to the original values (min. = 0; max. = 255). The manner of contrast adjustment was also simple; the shape of the tone rendering curve varied from horizontal (–100, min. contrast) to vertical (+100, max. contrast). In both cases, the adjustment value zero meant that the original remained unchanged (linear curve of 45 degrees). The tested adjustments are similar to those of Adobe Photoshop™. Tests were made with monitor images without compensating for the gamma value which was 2.2. The test image set consisted of 69 randomly picked RGB images.

The two-dimensional brightness/contrast adjustment tool is illustrated in Fig. 2. With this tool the two selected variables can be changed simultaneously by moving the cursor with a mouse.

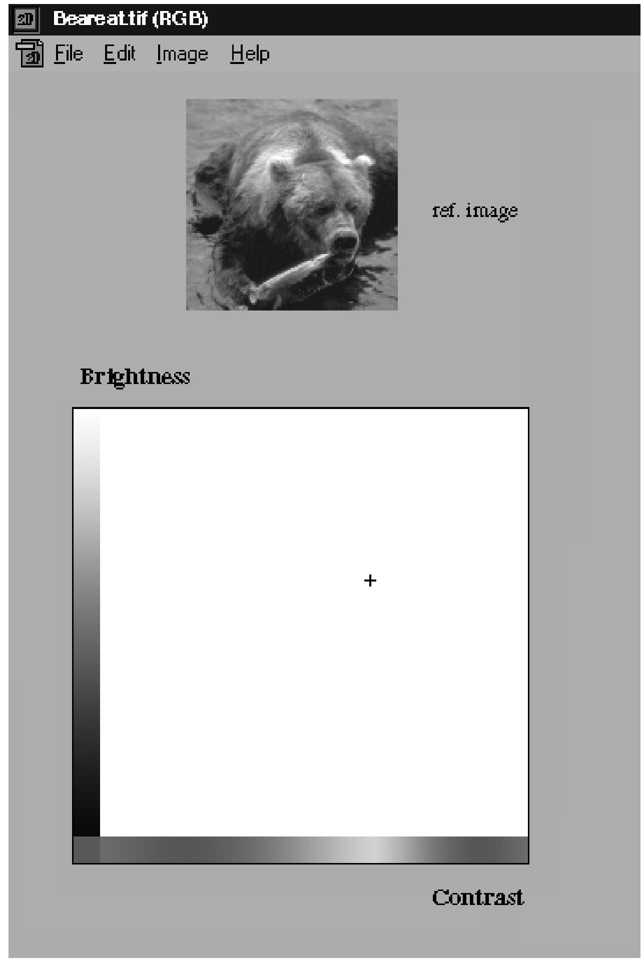

Figure 2. Example of a two-dimensional adjustment tool

When brightness and contrast were adjusted (i.e. visually optimized) successively one at a time (brightness first), optimum values were found quite easily for most images. Usually both sliders had to be accessed only once. The back and forth movement of the sliders took from 10 to 20 seconds (per slider). For many test images the need for adjustment was quite small, and taking the variation and the restricted repeatability of the adjustments into account it was difficult to show that specific values differed from the test person's optimum range. Less than 10 percent of the images clearly required more than two adjustments (usually three or four).

However, when adjustment was started with a brightness/contrast combination relatively far from the optimum range, finding the correct values proved to be time-consuming. Often several additional iteration rounds were needed. When arbitrary contrast values –33 and 33 were used as artificial starting points for the adjustments, brightness and contrast sliders had to be accessed almost three times on average before the test person's optimum range was reached. This is illustrated in Fig. 3.

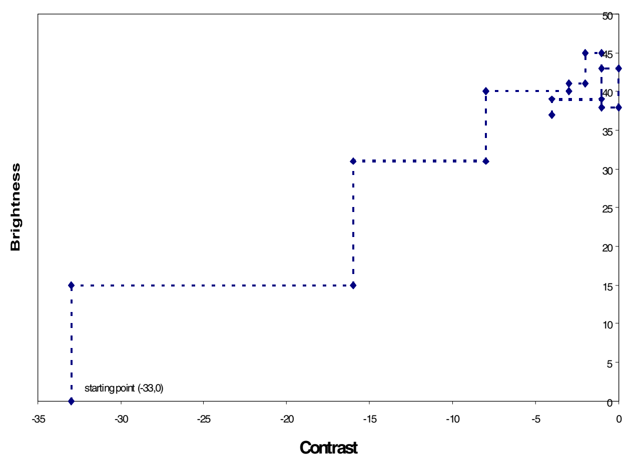

Figure 3. Typical example of brightness and contrast adjustment with two (1-D) sliders

Even though finding the optimum was difficult, it did not prove impossible. Despite the artificially bad starting point, optimum adjustment values were found for all test images. Sometimes this required some extra effort as is illustrated in Fig. 4.

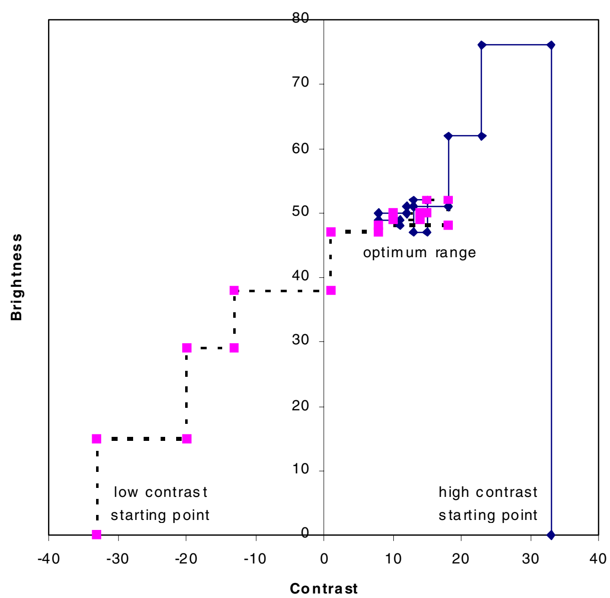

Figure 4. Example of separate brightness and contrast adjustment of low and high contrast "originals"

In addition to the preceding adjustment tests, visually assessed image quality was also empirically defined as a function of brightness and contrast. Results showed that the location of the maximum and the shape of these 2-D image quality functions varied considerably from image to image. Usually the original (0,0 adjustment variable values) was relatively near the optimum range. However, the shape of these functions was often irregular as in the example illustrated in Fig. 5. This explains, at least partially, why adjusting bad images is so tedious.

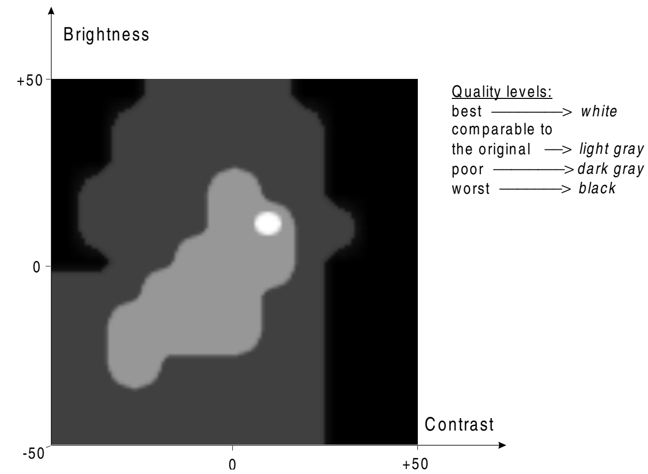

Figure 5. Image quality as a function of brightness and contrast

Automatic Guidance of Adjustment

Two-dimensional adjustment is a flexible way to change image properties. An inexperienced user, however, may not have any idea of the direction to move in the two-dimensional adjustment plane, and must therefore experiment a lot with different cursor movements. Thus adjustment is not necessarily much easier than with traditional 1-D adjustments.

Even though automatic image adjustment methods developed e.g. at the Helsinki University of Technology [1,2] cannot always predict exactly the right adjustment variable values, they can give a reliable estimate of the direction to move in the 2-D adjustment plane. When adjustment is guided in this way, even an inexperienced user can achieve good image quality quickly and easily.

User Training

Some kind of automatic guidance may be indispensable for a novice, but not necessarily for a well-trained user. It could be shown that a (very) experienced test person could define adjustment values for brightness and contrast quite accurately just by looking at the original picture. In fact, these evaluations gave slightly better results than could be attained with a (relatively successful) automatic algorithm. This algorithm was based on artificial neural networks and was trained with hundreds of images[3].

In practice, an experienced user is usually capable of moving the cursor very quickly quite close to the optimum zone on the 2-D adjustment plane. Thus it is possible to start close-tuning almost instantly.

Adjustment Times

In brightness/contrast adjustment tests a visual optimization of one 1-D adjustment took 10 to 20 seconds. If the adjustment was started with an image of poor quality, as many as six (2 times 3) separate adjustments were needed. An experienced user could attain the same quality level with a 2-D adjustment tool in 15 - 30 seconds; in many cases adjustment was more than a minute quicker. Normally, however, image adjustment (of relatively good originals) was reasonably easy and quick also when 1-D sliders were used. Still, 2-D adjustment was at least slightly less time-consuming in each case.

Discussion

In the hands of an experienced user, a two-dimensional image adjustment tool is an effective, flexible and intuitive means to control interactive color image enhancement. The need for instant visual feedback sets some limits to the use of this tool. The never-ending and rapid development of computers will, however, solve this problem. In the future, 2-D tools may well be used also for many complicated image adjustments. One example is contrast enhancement based on analysis of local color information[4] which the Helsinki University of Technology plans to implement as a part of a 2-D adjustment tool in the near future.

References

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Biography

Pekka Laihanen received his Ph.D. in Graphic Arts and Image Science from the Helsinki University of Technology (HUT) at Espoo in 1995. He has worked in the Laboratory of Media Technology at HUT. He has also done research work for the Hewlett Packard Barcelona Division. His work has primarily focused on different aspects of color image manipulation and enhancement.