Automatic Colour Correction

Pekka Laihanen, Mikael Lindholm, Simo Rouhiainen, Hannu Saarelma and Lassi Tuuteri
Laboratory of Graphic Arts Technology
Helsinki University of Technology, Helsinki, Finland

Pekka Kekolahti
Grafimedia/ICL, Helsinki, Finland

Abstract

Based on the former development work of efficient manual colour image manipulation tools, a fully automatic algorithm for correction of monitor images was developed. The software automatically corrects the colour balance, tone rendering and skin colours of a 24-bit monitor RGB image. The algorithm is based on colour gamut analysis and simple pattern recognition. Visual tests showed that automatic correction is capable of significantly improving colour rendering.

Introduction

It is very difficult to devise any unambiguous rules that would determine how the colours of a digital image should be corrected. In practical colour image manipulation the results depend on the visual feedback of the display device, the (subjective) assessment of this feedback and the properties of the colour image processing software. In the Laboratory of Graphic Arts Technology at the Helsinki University of Technology many software tools for effective colour image manipulation have been developed in the recent past. Many of these colour adjustments are based on the Lsα colour space which is specifically designed for image manipulation and has proved to be superior to other colour coordinate systems particularly in tone rendering adjustment.[1] Utilising the properties of this colour space, the colours of most images can be corrected in a simple and logical way with few separate colour adjustments. The automation of colour correction is based on the quantitative determination of a few image features which unambiguously select and define the colour manipulation measures that change the colours in the Lsα colour space.

For the present, automatic colour correction has been extensively tested in calibrated CRT monitors with standard EBU phosphors, reference white point CIE D_{65} and gamma 1.0. Preliminary results indicate, however, that the software is applicable also for various colour prints if the colour calibration between the printer and the monitor is accurate enough.

Description of the Colour Correction Algorithm

The automatic colour correction software has three basic functions: 1) it adjusts the L-component of the Lsα colour space using a curve defined with a method comparable to histogram equalisation, 2) it corrects the grey balance (or actually the overall colour balance) of a monitor image with a global chromaticity change and 3) it adjusts skin colours by detecting skin regions and changing these colours according to how they differ from the predetermined reference skin colour. Moreover, in some cases saturation is also adjusted primarily in order to compensate for the loss of colour vividness caused by other image manipulation measures. In rare cases these automatic colour adjustments may change image properties and particularly contrast in such a way that noise and spatial artefacts that are more or less hidden in the original image become more visually evident. This is compensated for with special median filtering that is adaptive to the tonal value of a pixel and its neighbours.

Tone Rendering

The automatic tone rendering adjustment is based on statistical analysis of the image content. A modification of conventional histogram-equalisation-type method is used. The results have proved to be very good. This is because the Lsα colour space was specifically optimised for this purpose in such a way that the changes in the L-component do not cause drastic or unnatural changes in saturation (not to mention hue, which is retained of course).

Colour Balance

The purpose of automatic colour balance correction is to detect and correct global chromaticity errors. The detection procedure is based on the calculation of numerical indices, of which each could serve as an indicator of possible chromaticity errors. By calculating several indices, the probability of an error can be decreased. If the indices indicate different chromaticity errors, no correction is made. This is also the case when the indices do not indicate any chromaticity errors. Typically an index is, for example, the chromaticity of the brightest area within the image.

The correction procedure is performed in the Lsα-colour space, where the correction is done by a global vector addition, possibly combined with 'compensating' saturation adjustment.

Skin Colours

An automatic skin colour recognition algorithm has been implemented to find skin regions from full-colour digital pictures. Areas that will be accepted as skin, must be large enough and their colour must be in a certain gamut in colour space. The regions found will be used in calculating average skin colour. To save computer memory, only a reduced version of the whole picture is used for these calculations. All the information needed for this algorithm can be found from the reduced picture. Spatial information is not needed after the average skin colour has been calculated.

Potential skin pixels are chosen on the basis of their probability to be of skin colour. For this algorithm statistical data have been collected from a large number of pictures. On the basis of this data it is concluded which parts in a picture are probably skin. From the original picture all those pixels are taken which have a probability value higher than the (relatively low) threshold value of skin colour probability. Each of these probability values corresponds to the colour and the location of a certain pixel in the original picture. A smoothing mask filters from the potential skin regions separate pixels and groups of a few pixels.

It is essential to detect every potential skin region separately. To make this possible every region is given a unique label and the connectivity between regions is computed. In every region, the distance to the nearest edge is calculated for all pixels with the sequential distance transformation. Distances will give information of the width and the shape of regions.

The final decision—of whether a region is skin or not—is made on the basis of probability distribution and distance values of the region.

The Performance of the Colour Correction Software

The performance of the automatic colour correction program was tested with test images of different kinds. Lighting conditions under which images were taken include daylight, electronic flash, tungsten and photo lamp. Positive and negative type films were used with under- and overexposure between ±3 stops. Images were captured with desktop scanner, transparency scanner, high quality drum scanner, Photo CD and still-video camera.

Visual tests with paired comparison were used as a test method. Some of the test persons had a background in graphic arts or in photography but many of them did not. Originals and corrected images were compared on a calibrated screen under standardised conditions. Four critical quality characteristics were assessed and points were given to: overall quality, grey balance, skin colour and contrast. Test data were analysed, ratings were calculated and images ranked. The scale of points was: -2 = corrected image appears clearly worse than original, -1 = corrected image appears slightly worse, 0 = no difference in quality, 1 = corrected image appears slightly better than original and 2 = corrected image appears clearly better than original.

The results proved to be dependent on the quality of the originals. Therefore, the test images were classified in three categories: poor, good and perfect. The quality of poor images improved very clearly, as illustrated in Figure 1. The variation of opinions between the 9 test

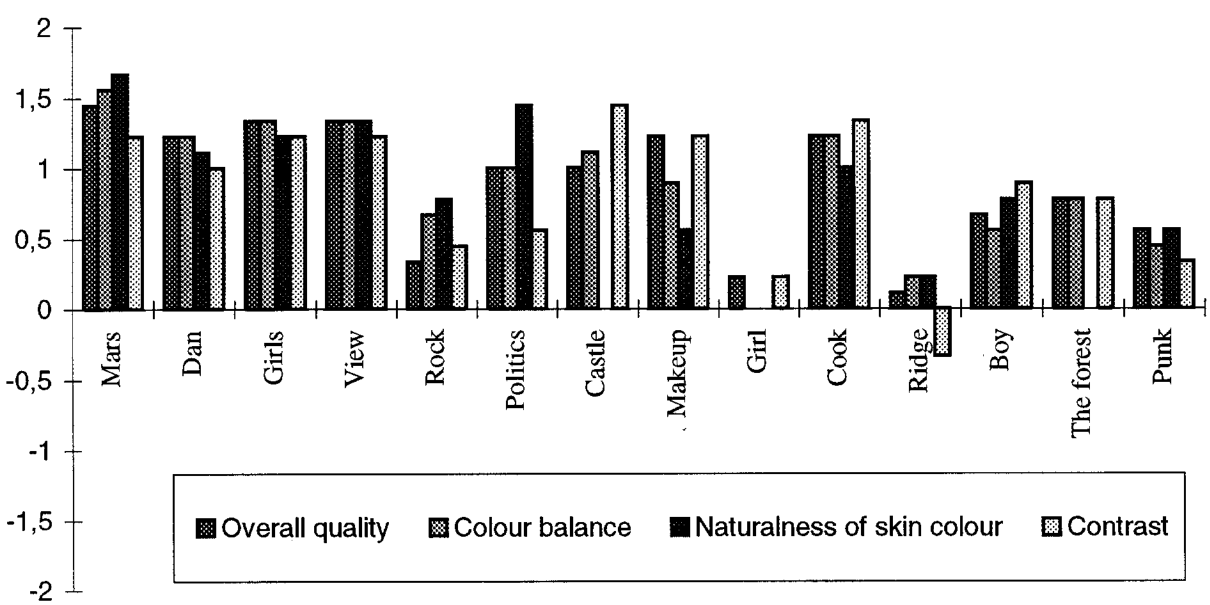

Figure 1. The effect of automatic correction on originals ranked 'poor'

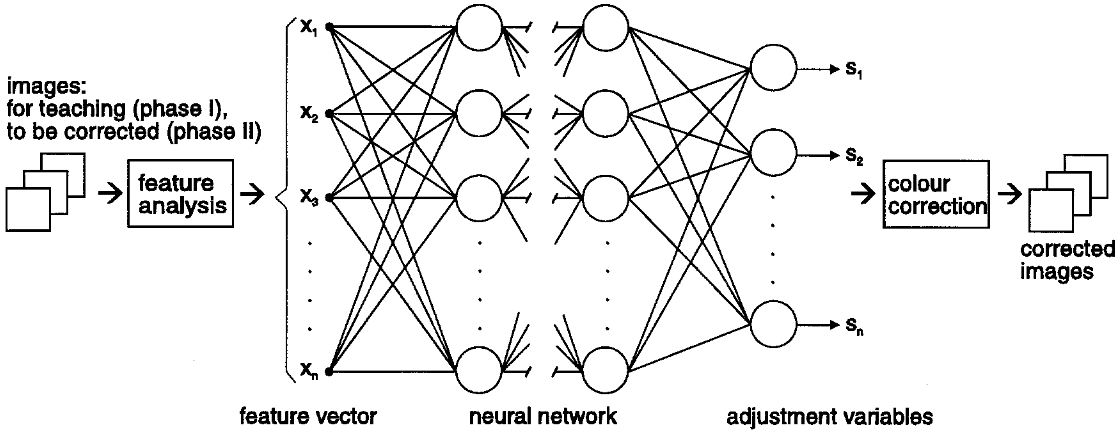

Figure 2. Neural network for automatic colour correction

persons does not, however, become evident from Figure 1, which only shows the average values of visual assessment of 14 different images. The results showed that on average, each image improved in overall quality. Hovewer, by using a binomial test with a level of significance $\alpha = 0.02$, 71% of images improved in overall quality statistically significantly. With the same level of significance, colour balance improved in 86%, naturalness of skin colour in 83% and contrast in 79% of images. The deviation from the average was mainly due to the divergences among the test persons.

As the quality of the original increased the effect of automatic correction decreased. For the images visually assessed as 'perfect' the software is not worth applying. In the category of 'good' images the quality growth was only moderate even though in most cases the quality of the images in this category did improve.

Future Plans

The results of visual tests showed that the automatic colour correction algorithm works quite well. It is felt, however, that to develop automatic colour correction further, a different kind of approach may be needed. The automatic software-based adjustment is now relatively close to, but still significantly different from the manual adjustment of an experienced reproduction professional. This difference, however, seems too complex to be determined just on the basis of logical heuristic deduction. Therefore, to improve the performance of the software to a level of reproduction craftsmen, neural network is implemented, as illustrated in Figure 2.

At the first stage the network is taught using a few hundred images of different kinds which are corrected by a colour reproduction professional. The features of the images and the software defining these features are to a great extent the same as used for the present in 'algorithmic' colour correction. Moreover, the adjustment variables of colour correction used by the human image manipulator are essentially the same as those used by the automatic software. Thus the work discussed previously gives a good basis for the introduction of neural networks in automatic colour correction. During the teaching period the neural network learns the connection between image features and the adjustment variables needed in colour correction. At the second stage (i.e. after teaching) the neural network can be used to automatically correct colour images.

Conclusions

It is becoming more and more common for new imaging tools to be aimed at users who are not experts in image processing. Therefore the demand for automatic algorithms that would guarantee acceptable colour image quality without user interaction is greatly increasing.[2,3,4]

Using only a few different primarily global colour adjustments in Lsα colour space, the visual quality of a colour image can be significantly improved. These colour adjustment measures proved to be simple and logical enough to be quantitatively determined on the basis of a few image features. This made relatively successful automatic colour correction possible. This is illustrated in Appendix. For the present, the software seems to be most beneficial when originals of poor quality are processed. In the near future, however, with the help of neural networks, more and more sophisticated colour adjustments will be made automatically enabling the 'fine tuning' of good quality colour images.

References

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Appendix 1. Examples of the automatic colour correction. Original images on the left and corrected images on the right side.