The Printer-Scanner-Feedback Method

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1.The scanning printing problem

The desktop publishing applications requires in many cases to scan one picture, referred as the original picture, to process it, and to print it.

The block diagram of the process is presented in figure 1.

Very frequently, the colors of the final printed image differ from the colors of the original. Different causes conduct to this phenomena but they will not be analyzed here.

One of the main problem of the desktop publishing applications is to reduce as much as possible the difference between the original and reproduced picture.

This paper introduces a method to transform the scanned image file in order to minimize the differences between the original and the reproduced picture.

The method is based on a device dependent calibration process, specific to the scanner and printer pairs devices used in application. The calibration process is not valid if the scanner or printer devices are changed, or processing parameters are changed. For one calibration, the nonlinearity, parameter settings and local color deviation of scanner and printer are compensated by color transformation. The calibration process can be easily performed periodically and does not requires any additional instrumentation for color measurement.

2.The printer-scanner-feedback method

The following notation was used:

P() : printer transformation function, that associates to a numerical value, c_n, of device dependent color space, an output color, $\mathbf{c}_{(x,y,Y)}$, (printed color).

S() : scanner transformation function, that associates to an input color $\mathbf{c}_{(x,y,Y)}$ a numerical value, c_n.

The process illustrated in figure 1 is described by the following equations:

$$\mathbf{c}_1 = S(\,C_{(x,y,Y)0}\,);$$

$$C_{(x,y,Y)2} = P(\,\mathbf{c}_1\,);$$

To obtain a printed color same like original scanned color, one restriction must be verified:

$$C_{(x,y,Y)2} = C_{(x,y,Y)0}\,, \qquad (1)$$

for all the color range of the input picture. In other words, the scanned colors can be reproduced accurately if they are included in the color gamut of the printer (constraint no. 1). The input colors outside of the printer color gamut can not be accurately reproduced.

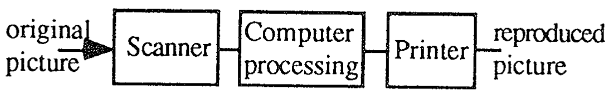

Fig.1. The desktop publishing usual configuration

The purpose of the method is to find the transformation, T() , between the original scanned color values, $\mathbf{c}_1$, and the color values to be printed, $\mathbf{c}_1'$,

$$\mathbf{c}_1' = T(\,\mathbf{c}_1\,)\,, \qquad (2)$$

such that the printed color, $C_{(x,y,Y)2}$, resulted from the numeric value $\mathbf{c}_1'$ to be equal to the original color, $C_{(x,y,Y)0}$, scanned and represented as numeric value $\mathbf{c}_1$. That is:

$$S(\,P(\,\mathbf{c}_1'\,)\,) = \mathbf{c}_1\,. \qquad (3)$$

Comparing (3) with (2) it results:

$$P(\,\mathbf{c}_1'\,) = S^{-1}(\,\mathbf{c}_1\,), \qquad (4)$$

$$T(\mathbf{c}_1) = P^{-1}(S^{-1}(\mathbf{c}_1)). \quad (5)$$

The transformation (4) is possible only for colors which are not metameric for scanner (constraint no.2).

The transformation (5) is possible for colors that are produced by unique components set from the device dependent color space of the printer (constraint no.3).

The **printer-scanner-feedback method** determines the reverse transformation of scanner and printer, specified by the relationship (5), as a color table transformation of the original scanned image file, derived for the entire printer color gamut.

The printer-scanner-feedback method takes advantage of a calibration process. The calibration process uses an uniform grid of test colors numerically generated for all the printer device dependent color space. The values of the color transformation function, which represent the solution of equation (3), are empirically derived as the pair sets of the color grid chart, on one hand as these are generated for printing, and, on the other hand, as these values are resulted after scanning the printed grid chart. The process is illustrated in figure 2.

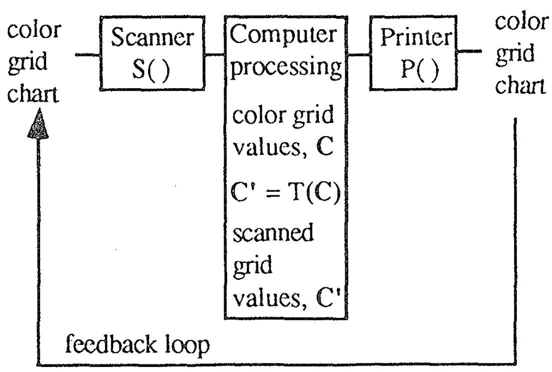

Fig.2. The printer-scanner feedback calibration

The computation of the color table transformation consists of the following steps:

1.the uniform grid of test colors is numerically generated and printed; the resulted colors represent the color grid chart;

2.the printed color grid chart is scanned and the direct color transformation table is computed;

3.the reverse color transformation table, T(), is computed, representing in fact the empirically derived solution of the equation (3).

Computing the reverse color transformation is a delicate task, because of the three limitations mentioned above:

1.the color gamut of the original image must be included inside the printer color gamut;

2.the metamerism of scanner device must be reduced to minimum;

3.the printed colors must be produced by unique numerical set.

3. Results and conclusions

The uniformity of the computer generated grid may conducts to a nonlinearity of the scanned grid chart. In this case, additional values can be generated in the range where the color transformation function has not enough values to be accurately defined. The process of covering the gamut of the color transformation is accomplished practically in 2 or 3 steps of iteration.

An interpolation process can follow if the color transformation table is performed for a limited number of samples of the color grid chart. Few method of 3-D color interpolation can be used[1],[2].

The calibration process was performed for a Sharp JX-450 color scanner and a Mitsubishi SCT-CT 220 color printer. The method was also successfully tested for same scanner and ink jet printer IRIS 3050. The color grid chart was selected as a 3D matrix 8x8x8 and the corresponding patches are organized on the printed paper as 32x16 array, in such order that, the scanning and the color table transformation to be automatically performed. The patches must be enough large to compensate the scanning errors determined by the boundary effect.

References

[1].K.D.Gennetten, RGB to CMYK conversion using 3-D barycentric interpolation, *Proceedings of the "Device-Independent Color Imaging and Imaging Systems Integration" Conference*, 1-3 February 1993, San Jose, California, SPIE Vol. 1909, p.116.

[2].J.M.Kasson, W.Plouffe, S.I.Nin, A tetrahedral interpolation technique for color space conversion, *Proceedings of the "Device-Independent Color Imaging and Imaging Systems Integration" Conference*, 1-3 February 1993, San Jose, California, SPIE Vol. 1909, p.127.