APPLICATION OF DIGITAL TECHNOLOGY IN THE ACCURATE REPLICATION AND PRESERVATION OF SLIDE-BASED WORKS OF ART

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Tate owns a number of installations in which projected 35 mm slides are the primary medium. Tate holds a master set of slides from which duplicates are made for display. Tate and the National Gallery (London) have collaborated to develop a general procedure to record colour slides digitally, capturing the full image detail of the original while maintaining high colour accuracy. The dual aims are to provide a digital record of the slides for future preservation and to explore the use of digital technology to make faithful duplicates. The latter should reduce the risks associated with conventional duplication and enable the master set to remain undisturbed in cold storage.

A Fuji Lanovia C-550 flatbed scanner was used to scan the slides. The recommended resolution for scanning 35 mm film is 2750 dpi (dots per inch) which represents a compromise between the highest image resolution and the lowest grain noise. An area of 40 **x** 35 mm was scanned at 2750 dpi in the 16-bits per channel mode. To ensure good colour reproduction, a 10 **x** 12.5 cm Kodak Q-60 color input target, which provides uniform mapping in the standard CIE (Commission Internationale de l'Eclairage) LAB colour space and is defined in detail in ANSI standard IT8.7/1 for transmission materials [1], was used to calibrate the scanner. The transmission spectra of the colour patches on the Q-60 chart were measured using a GretagMacbeth Spectro Scan. The CIE XYZ and CIE LAB values were then calculated from the spectra for either D65 or D50 illumination [2].

Surface dust on 35 mm slides is particularly noticeable when scanned at high resolution. Even careful dusting using anti-static brushes cannot remove all dust from the surface. To combat this problem we have devised a technique to remove dust digitally. The slide is scanned three times, briefly applying either a soft brush or an air-gun to both surfaces between scans to *move* any dust. The three digital images are then processed using a software package developed at the National Gallery [3]. After the three images have been aligned, the median (middle) value for each pixel is selected and output to the final image. In this way, pixels due to features that move between images are automatically filtered out; taking a mean of the three values would have made the dust less visible but would not have removed it as successfully.

After dust removal, the 'cleaned' digital image obtained was still expressed in terms of the scanner's red, green and blue (RGB) channels. To correct the colour, the scanner RGB values for each colour patch on the Q-60 chart were averaged and compared with the corresponding CIE XYZ values measured with the spectrometer to derive a 3 **x** 3 colour calibration matrix. Before deriving the 3 x 3 matrix, the 24 grey levels on the Q-60 were compared with their CIE XYZ values to correct any non-linearity. The linearity correction and the colour calibration matrix were then applied to the 'cleaned' digital images to produce slide images calibrated in CIE XYZ; these were converted to CIE LAB (D65) to serve as master digital copies of the original slides. The average colour accuracy for the patches on the Q-60 chart was 1.7 AE_{2000}units, with a maximum of 8.8 [4]: the largest errors were found in the deep blue patches.

A Polaroid Propalette 8035 slide-writer was investigated for slide duplication [5]. The slide-writer works by converting the data in a digital file into an image on a small cathode ray tube (CRT), which is imaged through coloured dichroic filters onto a factory-matched 35 mm film camera. Using the 2750 dpi data scanned earlier, an image of around 3790 **x** 2540 pixels is projected onto the film. To produce the signals for the writer, the CIE LAB (D65) image is converted into sRGB colour space, which is the standard for CRTs [6].

Because the colour gamuts of CRT systems are typically smaller than those of Ektachrome transparency films, a CRT-based slide-writer cannot reproduce the full colour gamut of a slide film. It is much more difficult to calibrate a slide-writer than a scanner, because the (three) dyes in colour films do not behave independently when exposed, and the variation in film processing is hard to control. However, slides produced from a sRGB file of the Q-60 chart, using a Kodak Ektachrome 100 Professional film and scaling each channel by 1.2, gave optimum results. The average colour error was 5.8 E_{2000} units, with a maximum of 17.5: the largest errors were found in the green patches. The same Q-60 file was exposed on two separate rolls of film of the same stock and both were developed in-house over a period of two to three days. These were found to differ by an average of 1.4 E_{2000} units, with a maximum of 4.

These results are comparable with those of Fairchild *et al.*, who modelled a CRT-based slide-writer using a set of 21 single coloured ramps [7]. They built a 3-D LUT (look up table) that gave the RGB values necessary to produce the appropriate colour on the slide. The average colour accuracy was 5.7 E_{ab} units, with a maximum of 10.8. We have opted for a simple sRGB scaling, since the small gain in colour accuracy through detailed modelling is offset by the complexity of the LUT method.

The procedures outlined above were applied successfully to *Green* (Tate No. N01743), a set of colour slides made by David Tremlett in 1973. The slides have been recorded accurately using the flatbed scanner and extraneous dust has been removed from the images. The non-linearity, restricted gamut and variability of slide film remain the limiting factors, rendering the slide-writing phase subject to the greatest error. The slides produced from the digital records are, however, more accurate than those produced by routine duplication. The great advantage of the system described is that the original slides no longer need to be handled when duplicates are required; and because the input stage is highly accurate, the colour of these originals is now recorded in a more permanent form for future reference and reproduction.

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