# Colour analysis of inhomogeneous stains on textile using flatbed scanning and image analysis

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## Abstract

*This paper describes a method for the determination of the colour of inhomogeneous stains on textile using flatbed scanning (FBS) and image analysis (IA). The method can be used to assess the cleaning performance of laundry detergent products. Stains on textile were visualised using a standard flatbed scanner. A fully automatic procedure was developed using image analysis (IA) software. Different colorimetric calibration procedures were investigated. The method was tested on 24 different types of stain on cotton cloths and compared to the analysis using a spectrophotometer. FBS-IA can be used to analyse colour changes on stained textile. The method is sufficiently accurate and precise to screen different laundry detergent products. FBS-IA is fast, easy to use and cheap. Images can further be used to analyse the spatial distribution of inhomogeneous stains. The best agreement between FBS-IA and spectrophotometer was obtained using a 3 by 9 transformation matrix without linearization of the RGB response.*

## Introduction

The cleaning performance of laundry detergent products is usually evaluated by washing standard soiled fabrics under standardized controlled conditions. Stains are often applied homogeneously on the textile making it easier to screen different products. However to perform evaluations which are more close to a consumer relevant environment, non-homogeneous stains have to be included. Methods for the assessment of cleaning of homogeneous stains on test fabrics are standard applied using spectrophotometers [1,2], colorimeters or visual assessment [3]. The reflectance measurements are made on the stained areas before and after washing. These methods are time consuming and will give no information about the in-homogeneity of the stain. Stains on textile can be visualised using a standard flatbed scanner (FBS). A fully automatic procedure was developed using image analysis (IA) software. FBS scanners, also called desktop scanner, are the most versatile and commonly used scanners found in literally all offices and are available at low cost (much lower than for imaging systems using a camera and an illumination cabinet [4]). FBS is robust and independent of external light conditions. The application of FBS for IA has been growing rapidly during the last years [5]. This article presents a method for the determination of the colour of inhomogeneous stains using FBS and IA. Different colorimetric calibration procedures were investigated. The method was tested on 24 different types of stains on cotton cloths and compared to the analysis using a spectrophotometer.

## Experimental

### Apparatus

The experiments were carried out using a single pass Heidelberg Linoscan Hell jade FBS. The scanner was used in the reflective mode, 24 bits RGB scale and a resolution of 85 dpi without contrast stretching or other corrections. The FBS method was compared with a Datacolor Spectraflash 600 plus spectrophotometer measuring the reflected light from 420nm till 700nm in steps of 10nm. This spectrophotometer uses a Xenon lamp as light source. The Xenon light is filtered to match the CIE standard observer response. It was set at $10^o$ and D65 illuminant conditions. The Datacolor spectrophotometer was calibrated using a white tile and a light trap. An aperture with a measuring diameter of 26 mm was used.

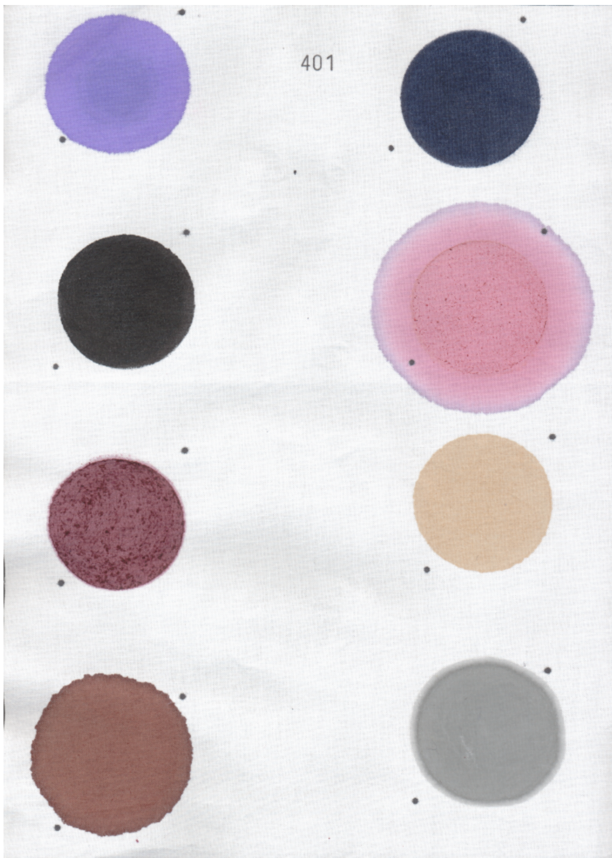


Figure 1. Example of a test cloth containing 8 different stains.

**Materials**

Cotton cloths with a size of 21 cm * 30 cm containing 8 different stains per cloth with a diameter between 4 and 8 cm were used to set-up the method (Figure 1). These test cloths were measured before and after washing using each 10 different washing conditions (e.g. product and dosage) and 5 samples per type of stain. For the final method test cloths were made containing a larger number of stains per cloth and marking the stained area with a circle to simplify the IA procedure (Figure 3).

**Procedure**

Test cloths were placed on the scanner surface and aligned with the top-right corner and scanned with closed cover. For both FBS and spectrophotometer methods dark grey plates with the same colour were used as background (covering the cloths). Images were analysed using Leica QWin IA software. In order to define the locations of the 8 stains, only the unwashed cloth was used. In this case the stains can easily be distinguished from the background, whereas in the case of thoroughly washed stains automatic detection is difficult or impossible. A captured image of a test cloth was divided into eight overlapping rectangular areas in such a way that only one complete stain was surrounded by a rectangle. The white background in a defined rectangle is automatically detected by the software using thresholding [6]: defining a range of brightness values belonging to the foreground (textile) and rejecting all of the other pixels to the background (stain). After removal of unwanted features (e.g. small spots) and inversion of the detected area using binary image processing, the centre of the remaining spot was measured. These measured locations (centres) were stored on disk and used for the measurement of the (same) washed cloth later on. If the automatic detection fails, viz. anything else but one stain found, a procedure is called to point out the centre by using the computer's mouse. A fixed spot size, smaller than the smallest stain spot was used (Figure 2). By using a smaller spot size the influence of possible shrinkage after washing is minimized. A circular measuring spot (mask) was drawn automatically around each spot location for the 8 stains. Using this mask the average RGB values for the stains were measured. The stains were measured with the spectrophotometer on four different locations within the stained area. Procedures for colorimetric calibration of the FBS were investigated using a Fuji IT8 and Gretag Macbeth (24 patches) colour targets. The tristimulus values XYZ of each colour patch measured by the spectrophotometer and the corresponding RGB values measured by the FBS were used to calculate the transformation matrix [7]. The XYZ values were converted to CIE L*a*b* colours. A FBS has non-linear transfer characteristics. The first approach was to use a linearization of the RGB response using the gray patches of the colour targets resulting in RGB values ranging from 0 to 255. After which a simple 3 by 3 transformation matrix was used. The second approach was to use a 9 by 3 matrix on the uncorrected RGB values. In the 9 by 3 matrix the XYZ values were linked to the higher orders of RGB:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = M \cdot \begin{bmatrix} R \\ G \\ B \\ RG \\ GB \\ RB \\ R^2 \\ G^2 \\ B^2 \end{bmatrix} + \begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix}$$

In which M is the 9 by 3 matrix and and $X_0$, $Y_0$, $Z_0$ define the colour of the nominally white object colour stimulus with $Y_0$ equal to 100.

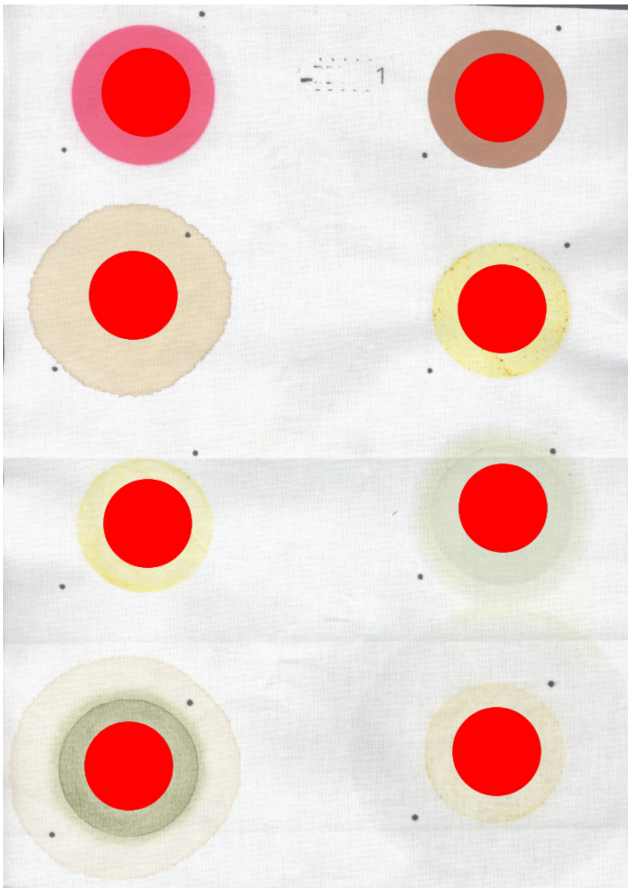

Figure 2 FBS image of a test cloth with overlay of a measuring mask in red.

Colour measurements for the assessment of cleaning performance are used to estimate the colour differences before and after washing [8]. The difference between two colours can be expressed as ΔE, the distance between two points in L*a*b* space and is calculated as follows:

$$\Delta E = \sqrt{((\delta L^*)^2+(\delta a^*)^2+(\delta b^*)^2)}$$

 


Figure 3 FBS images of a test cloth before (top) and after (bottom) washing.

## Results

The colours of the 24 different stains before and after washing (1200 samples) were ranging from 25 to 88 for L*, -11 to 56 for a* and -38 to 53 for b* (see Figure 4). After washing the colour of the stains are shifted to higher L values (lighter colour).

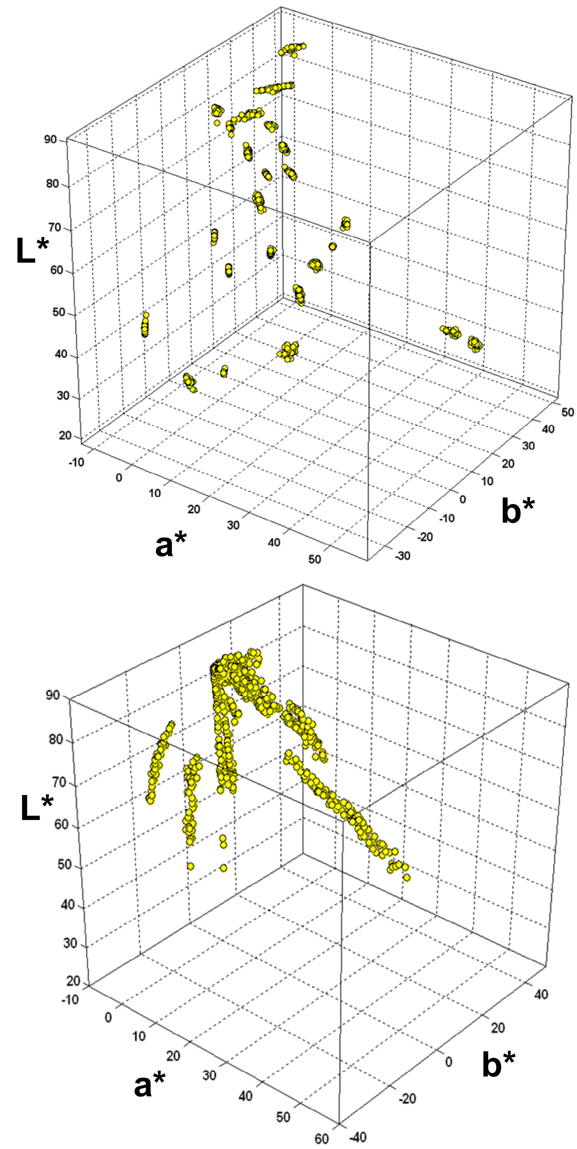


Figure 4 CIE Lab colours of 24 different stains before (top) and after (bottom) washing.

The differences between the CIE L*a*b* colours of the washed and unwashed stains, expressed as ΔE are used to assess the cleaning performance. The ΔE values obtained by FBS and the spectrophotometer are compared in Figure 6. The FBS results shown in this figure were obtained after calibration using a 3 by 3 transformation matrix and a 9 by 3 matrix, both with and without linearization of the RGB response. Linearization of the RGB response for a 3 by 3 matrix resulted in a much lower systematic difference between both methods (slope = 0.62 and 0.80 for Figure 6A and Figure 6B, respectively). However the scattering around the trend line remained large. The best agreement between both methods was obtained when a 9 by 3 matrix calculation was used. Linearization of the RGB response resulted for the 9 by 3 matrix in a lower correlation ($r^2$ = 0.93 and 0.86 for Figure 6C and Figure 6D, respectively). An IT8 chart was used as calibration target. Calibration using the Gretag Macbeth Color Checker resulted in a poor correlation between FBS and spectrophotometer. This is due to the fact that the measured chromaticity values of not all stains were included into the calibration gamut. Stains with a reddish colour were outside the borders of the gamut. For the IT8 target nearly all measured values were inside the calibration gamut.

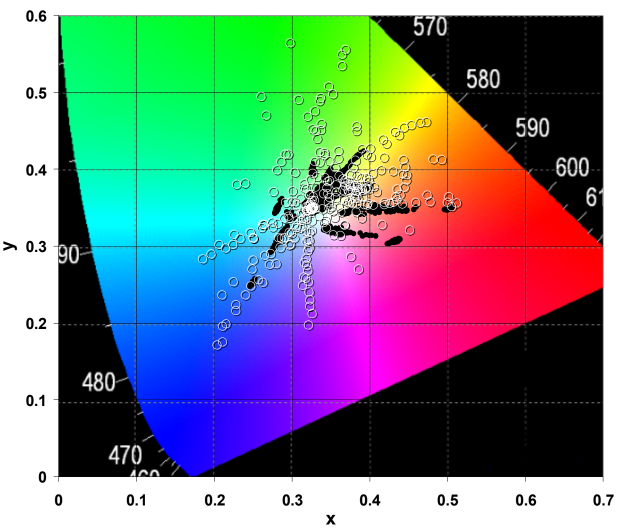


Figure 5 Chromaticity graph with x and y values of measured stains (black) and IT8 patches (white) obtained using a 9 by 9 matrix without linearization.

The precision of the FBS-IA method was tested by measuring a selection of the samples on 2 different days (day1 & 5) and using 2 different scanners. An average correlation of 0.994 was found between the L*a*b* values measured by the 2 scanners and an average correlation of 0.995 was found for the L*a*b* values between the L*a*b* values measured on different days. The precision of the FBS-IA method is good. As a measure of the long term stability the Gretag Macbeth Color Checker was measured over a period of 3 months. The colour differences relative to t=0 were smaller than 1.4 (see Figure 8).

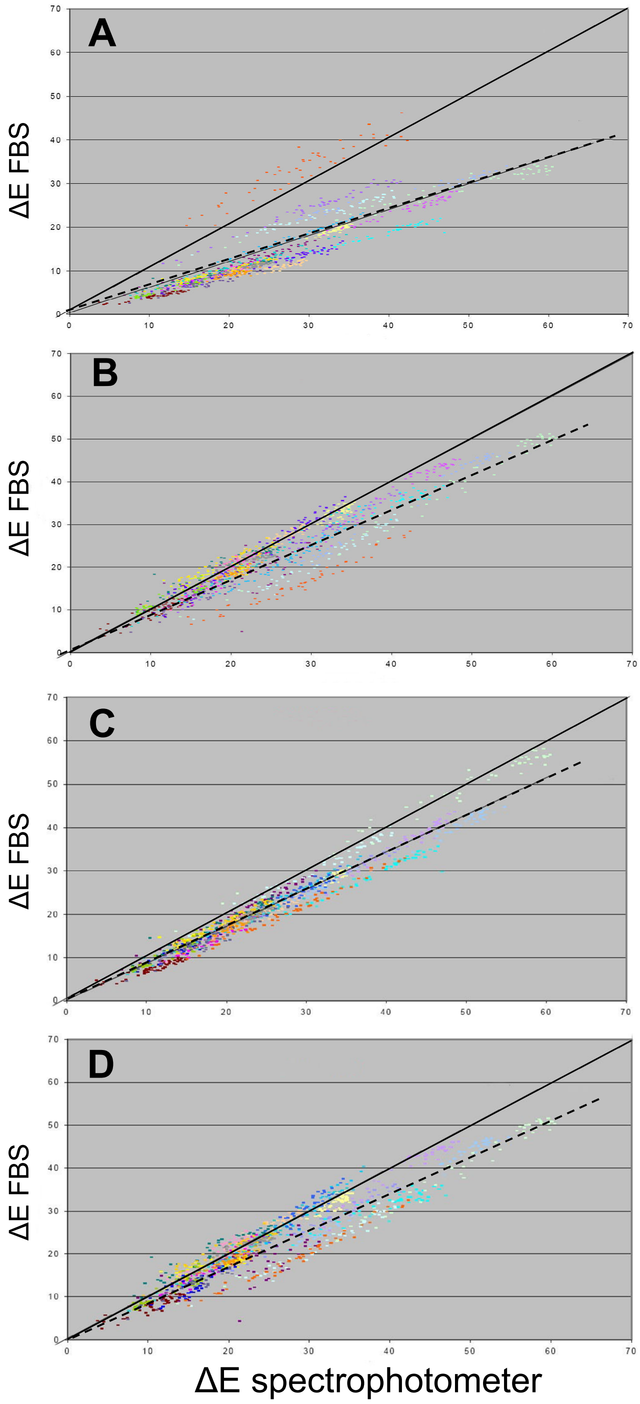


Figure 6. Colour difference (ΔE) between washed and unwashed stains measured by FBS and spectrophotometer. For FBS the following calibration methods were used: a 3 by 3 matrix without (A) and with (B) linearization and a 9 by 3 matrix without (C) and with (D) linearization (solid line: y=x; dotted line: trend line).

The potential of the FBS method for the analysis of inhomogeneous stains on textile was shown by analysing mud stains on cotton cloths washed with 2 different detergent products. The soiled cloth was divided in to two parts from which one part was washed. The stains were only partly cleaned (Figure 7). The stain of the cloth washed with product A is well visible whereas the stain remaining after washing with product B is difficult to detect visually. The colour difference (ΔE) was calculated relative to clean white cotton. The surface plots in Figure 7 show clearly the spatial distribution of the stain. The average colour differences of the washed stains are 9.5 and 3.0 for the cloths washed with product A and B, respectively.

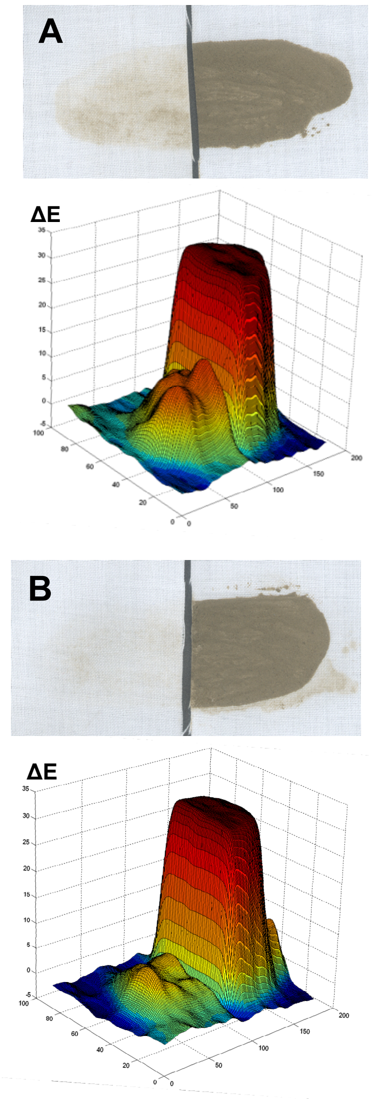


Figure 7 FBS images of mud stains on cotton cloths. Left parts of the cloths were washed using different detergents (A and B). Surface plots showing the spatial distribution of the colour relative to clean white cotton with ΔE values ranging from 0 (dark blue) to 35 (dark red).

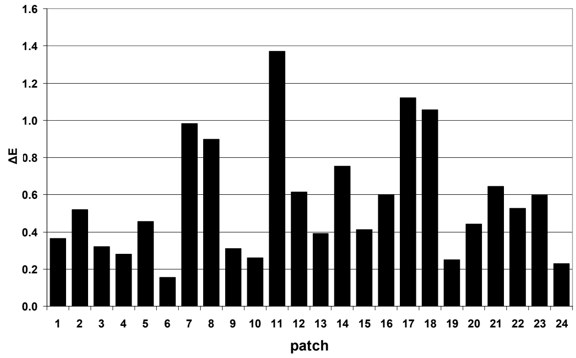


Figure 8 Colour difference of patches of the Gretag Macbeth Color Checker after 3 months (relative to t0).

## Conclusion

Flatbed scanning and image analysis (FBS-IA) can be used to analyse colour changes on stained textile. The method is sufficiently accurate and precise to assess the cleaning performance of laundry detergent products. FBS-IA is fast, easy to use and cheap. Images can further be used to analyse the spatial distribution of inhomogeneous stains. The best agreement between FBS-IA and spectrophotometer was obtained using a 3 by 9 transformation matrix without linearization of the RGB response.

## References

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## Author Biography

*Gerard van Dalen has been working in Unilever Research Vlaardingen for 28 years and was manager for 12 years of the Atomic and Vibrational Spectroscopy unit. He is currently involved as a research scientist in the application of IA techniques for advanced imaging techniques (2D, 3D and 4D) to obtain quantitative information of the micro and macro structure, composition, texture, size, shape, colour and appearance of foods, detergents and related products. He is author of 25 papers on Spectroscopy, Microscopy and Image Analysis.*