INTRODUCTION
Staining on fabric is a major concern to consumers. The evaluation of stain release has long been an important issue for researchers in the laundry and dry-cleaning industries and for others studying aspects of fabric-appearance retention [1–2]. Methods to evaluate stain release traditionally have involved visual assessment. The test used most often is AATCC Test Method 130 (Soil Release: Oily Stain Release Method) [3]. Due to the subjective nature of the rating method and the limited types of stains, the reliability and accuracy of the results are sometimes questioned [4–6]. More objective instrumental methods such as Datacolor, WSB-L and so on based on reflectance measurements and calculations are also widely used in industry. Other instrumental for example, microscopy, fluorometry, were also used in the test. All of them had some disadvantages, such as it must be tested in laboratory by special researcher and it had limited tested area [7–10]. Recently, image analysis has been applied into evaluating fabric performance, such as colour fastness, pilling, wrinkling and so on [11–17]. It could analyse the whole image of stain. The image analysis based on the luminance histogram is used to analyse the image, but it lost many colour information. Then the colour histogram of an image is being studied. The colour histogram of an image represents the distribution of the composition of colours in the image. It shows different types of colours appeared and the number of pixels in each type of the colours appeared [18].

In this paper, standard stain cloths were being studied, such as sebum, carbon black, blood and so on. They were being washed under different washing conditions, then we analyzed the washing efficiency. We also analyzed the colour histogram of stain image which was got through Fuji film before and after being washed. The relationship between the results got by image analysis and objective instrument was discussed.
EXPERIMENTAL DETAILS

Experimental materials

Five different kinds of stain cloth were used in our study, they were shown in table 1. Color Tester (7000A, EYE Macbeth) and Digieye Digital imaging quick rating system (d/8), England were used.

Sample treatments

The stain cloth were being washed in Front-loading Washing Machine (JW75-12SUJB, JiDe), and the washing conditions were shown in table 2. 20 groups were being discussed. During each washing, five kinds of stain (6 cm × 6 cm) were sewed on the load cloth and being washed together. In order to reduce the error, five pieces of each stain cloth were placed.

Washing efficiency

Washing efficiency, a measure of the wash effect, is an important index to evaluate the quality of cleaning (equation 1). Y represented the Green primary stimulus of tristimulus values. Y of the stain before and after was got through the Color Tester. And the washing efficiency was calculated as follows, the final result of washing efficiency is the average of all the result in the group.

\[
D_r = \frac{Y_w - Y_s}{Y_o - Y_s} \times 100
\]

In the equation, \(D_r\) is Washing Efficiency, \(Y_w\) – Post-wash Green primary stimulus of stained fabric, \(Y_s\) – Before-wash Green primary stimulus of stained fabric and \(Y_o\) – Original Green primary stimulus of fabric.

Image analysis

Image acquisition was the first step of the machine vision system for the stain release evaluation. The stain cloth was photographed in a standard, black box [19]. There is a circular standard light inside the top of the box. The camera was put in the middle. In the box, there was a sample holder in the box. Then the samples were put on it to be photographed. After the images were got, they were cut into uniform size to be analyzed in the later discussion.

Image processing

The distinctive features of a stain are its colour and intensity. In order to get accurate information, the colour information was discussed. This was achieved by transforming the image from RGB plane to the l, a, b. And the colour histogram of stain image was studied via Matlab software. The average distance of each pot of the histogram was calculated. Through this, the similarity of two images before and after being washed was calculated.

RESULTS AND DISCUSSION

Washing efficiency

JMP is a common experimental design software, which is used to analysis the level of multiple factors experiment. In our study, we chose “automatic detergent on the optimization of experimental data” for analysis. As is shown in table 2, the hardness of water, dosage of detergent and the load were changed. After being washed, the washing efficiency of stains was got according to equation 1. On the surface of the stain, five small areas of both sides were tested, and the average were got. The results were shown in table 3. The stains which were being washed under different washing conditions had different washing efficiencies. This was because those different stains had different performances, then the washing efficiencies of stains were different from each other. But for each stain, the washing efficiency changed between certain ranges.
Image analysis
According to measurements mentioned above, the image of the stain cloth before and after being washed was got through standard image acquisition system, which was listed in experimental details. The pictures of five kinds of stains from left to right were shown in figures 1 and 2. Figure 1 showed the five kinds of stain before being washed. Figure 2 showed the five kinds of stain after being washed. It could be seen from figures 1 and 2 that the colours of stains were changed before and after being washed.
Five pieces of each stain cloth were got, and each image was analyzed. Take one stain for example, figure 3 showed the five pieces of blood being washed in Group 2. As is shown in figure 4, X-axis represented the value of I, a, b, and Y-axis represented the distribution at each position. We extracted the distribution of I, a, b of each image, calculated the distance of histogram of stains before (blue line) and after (red line) being washed. Then we averaged the results, the results were shown in table 4. The value of similarity meant the degree of the similarity of two images. The higher the similarity, the more similar the image. This meant the stain was largely unwashed. The results of 20 groups were got in the same way and were shown in table 5. It described the similarities of stains before and after being washed, which were got through the image analysis.

Date analysis
In order to evaluate the results of the image analysis, we use SPSS to discuss the relationship between the data got by objective instrument and image analysis. The results were shown in table 6. The higher the similarity, the more similar the image. This meant the stain was largely unwashed. On the contrary, the higher the washing efficiency, the more clean the stain cloth. So the Pearson correlation coefficient was negative. Table 6 showed the relationship between the data got by two different ways.
in the condition of 95% confidence interval. From table 6, we could see that in less than 0.05 level, two groups of data had a significant correlation, the results varied from 0 to 0.030. But the absolute value of Pearson correlation coefficient was not up to 85%. It was because the image analyzed the whole image, meanwhile the certain area were taken for analysis in the test of objective instrument. In addition, the stain was uneven distributed. It could be seen in figure 3, there was white mask on the stain after being washed.

The cloths were got duty through the way of pad, there are stains on both sides of cloth. The stain was used in the test of detergent ad washing machines as standard cloth. Except this, we change the cloth, such as the material (polyester) of the cloth, the kinds of stain, and so on. We tested the cloth contained stains through painting stains on the cloth. The results of image analysis and objective instrument were coefficient.

CONCLUSIONS
The study presents a computer vision for evaluate the degree of stain release. Pictures of stains before and after being washed were got through image acquisition system and the histogram based on distance were draw and similarity of stain before and after was calculated. The similarity described the degree of washing. The higher the similarity, the more similar the image, the less stain was washed out. The results showed that different results got from washing efficiency and image analysis had a significant correlation. The image analysis could be used to evaluate the stain release well.

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