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# Color printed image defect detection based on the image feature match

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## ABSTRACT

Color printed image defect detection algorithm based on the sift method and YIQ model is proposed. At first, pre-treatment is conducted with median filter for the color printing image. Feature points of color printing image are extracted with Beaudet algorithm, and then, they are described with sift algorithm. For each sift feature point, YIQ color feature is extracted. Finally, the feature vector about sift and YIQ feature of the feature points in the color printing image and standard specimen page image are matched, for determining the defect region of the color printing image. According to the experimental results, this method can detect the defects of color printing image rapidly and effectively.

## KEYWORDS

Color printing image; Defect detection; Feature match; Sift feature vector; YIQ color space.

## INTRODUCTION

With the rapid development of printing technology, the production package of biotechnology and food becomes more and more beautiful than before. At present, color printing has taken a huge market share in printed matter for package. In order to discover quality problems like bad color, defeats, etc. and avoid the occurrence of defective goods in batches timely, accurately and effectively, the research on the online detection of color printing image is of great significance.

In 2009, N. G. Shankar proposed that subtractive correlation could be applied for scanning the image and golden master, and then they would be compared and analyzed for checking if there were defeats in the color printing image. However, the method applied the green information channel for too many times, and it was only applicable for the web offset printing[1]. In 2011, Marie Vans detected the defeats in printing image with variable data between the printing image and referential image acquired on the basis of the structural similarity information measure[2]. Min Xu applied the Line-labeling algorithm for detecting the defects in printed matter. However, the printing image shall be acquired after being scanned for two times, which may take too much time[3]. In 2014, Jianhua Ding detected the defeats in color printing image with background subtraction method, in which the non-defective pixel was taken as the background, while the defective pixel was taken as the foreground, but the detection precision is not accurate[4].

In order to solve the instantaneity and accuracy of the defect detection for color printed matter, the defect detection algorithm based on SIFT and YIQ model was proposed for the color printed matter. In the second section, the constitution of the detecting system of color printed matter was introduced. In the third section, the implementation of color printing image detection algorithm based on SIFT and YIQ model was introduced specifically. In the fourth section, it was the experimental result. And eventually, it was the conclusion.

## CONSTITUTION OF THE DETECTING SYSTEM OF COLOR PRINTED MATTER

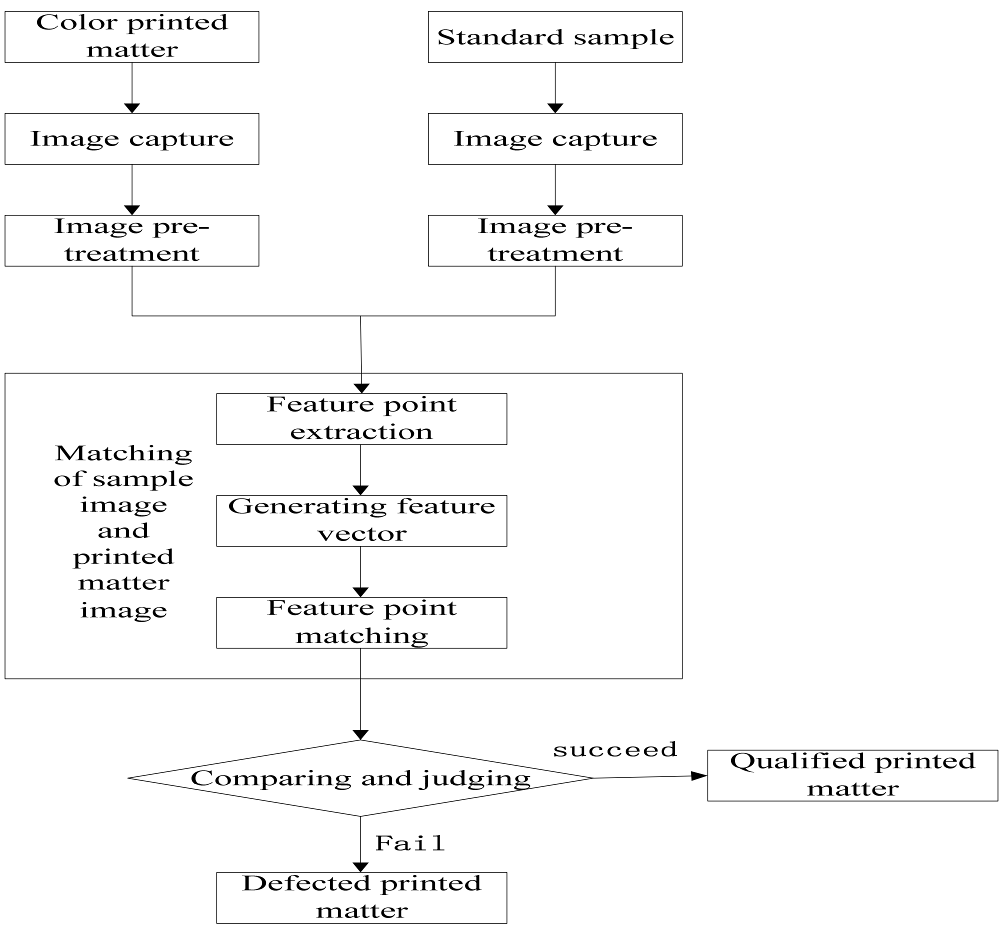


**Figure 1 : Defeats detecting flow of color printed matter**

Online defect testing flow of color printed matter is shown in Figure 1. Industrial COMOS camera was applied to accomplish the acquisition of printed matter image and sample image. In order to guarantee the accuracy of the inspection, median filtering is pretreated for the image acquired. The feature point is extracted with the Beaudet algorithm. The SIFT vector and YIQ color feature of the feature point is matched to the description feature vector with the SIFT algorithm. If the sample image cannot be matched to the printed image successfully, there would be defeats in the printing quality.

**Image capture**

Compared to the traditional civil camera, the industrial camera is high in image stability, high transmission capability, high anti-jamming capability, etc. According to the types of chip, it consists of CCD (charge coupled device) and CMOS (complementary metal oxide semiconductor). CCD is currently the most common image sensor, integrating the photovoltaic conversion, electric charge storage, load transfer, signal reading, etc. as typical solid image device. The typical CCD camera consists of optical lenses, time series, synchronizing signal generator, vertical actuator, simulation/digital signal processing circuit. As a functional device, CCD is characterized by burnt-free, lag-free, low voltage and low power consumption etc.

At the beginning of the 1990s, with the development of VLSI manufacture technology, CMOS image sensor was developing rapidly. CMOS image sensor mainly integrates the photosensitive element array, image signal amplifier, signal reading circuit, analog-digital conversion circuit, image signal processor, controller, etc. on a single chip. At present, CMOS image sensor is mainly widely applied in high-resolution and high-speed situation due to the good integration, low power consumption, high-speed transformation and wide dynamic range.

The instantaneity required by the online printing defeat detection is a kind of high-speed occasion. Therefore, CMOS industrial camera is applied to capture the printing image.

**Image preprocessing**

During the printing process, due to the mutual relationship between paper and ink, the captured printing image is usually vague in edge, which is not favorable for the sub-sequent image registration. Therefore, filtering and noise reduction should be conducted for the printing image waiting to be checked.

The median filtering method is a non-linear smoothing technique, which may set the grey level of each pixel point as the mid-value of the grey value of all pixel points within the adjacent window of the pixel point. This method may eliminate the isolated noise point by altering its pixel grey level with the surrounding pixel grey level. The two-dimensional median filter can be represented by equation (1).

$$F_{ij}(\mathrm{x},\mathrm{y}) = \mathrm{med}\{\mathrm{f}_{ij}(\mathrm{x},\mathrm{y}), \mathrm{f}_{ij}(\mathrm{x},\mathrm{y}) \in A\} \quad \textbf{(1)}$$

In the equation (1), $\mathrm{f}_{ij}(\mathrm{x},\mathrm{y})$ is the pixel value of the $i^{th}$ row and $j^{th}$ line of the two-dimensional image, and A is the adjacent window of the point.

Realization method: ⑴ The pixel values are sorted, which taken from certain sampling window in the image; ⑵ The mid-value after sorting takes place of the processing pixel value. In practice, the window size is usually 3*3 and 5*5, it shall be increased gradually till the filtration effect is satisfactory. The method can not only keep the image edge information and details, but also eliminate and reduce the noise interference.

**Defect detecting of printed matter image**

**Foundation of SIFT algorithm**

In 1999, David G.lowe from British Columbia University proposed the local feature description operator, namely the SIFT (Scale Invariant Feature Transform). On the basis of scale space, it remained invariant in zooming, rotating and brightness variation.

SIFT algorithm description[5]:

**Building the scale space and detecting the extreme point**

The scale space of an image $L(\mathrm{x},\mathrm{y},\sigma)$ is the convolution operation of the original image $I(\mathrm{x},\mathrm{y})$ and the variant two-dimensional Gaussian function $G(\mathrm{x},\mathrm{y},\sigma)$, as shown in equation (2).

$$\begin{aligned} L(\mathrm{x},\mathrm{y},\sigma) &= G(\mathrm{x},\mathrm{y},\sigma) * \mathrm{I}(\mathrm{x},\mathrm{y}) \\ G(\mathrm{x},\mathrm{y},\sigma) &= \frac{1}{2\pi\sigma^2} e^{-(\mathrm{x}^2+\mathrm{y}^2)/2\sigma^2} \end{aligned} \quad \textbf{(2)}$$

The Gaussian difference multi-scale space of the image (DOG) $\mathrm{D}(\mathrm{x},\mathrm{y},\sigma)$, the image key point in the scale spatial domain is generated by multiplying the adjacent scale Gaussian difference with the constant scale factor *k* and image, as shown in equation (3).

$$\begin{aligned} D(\mathrm{x},\mathrm{y},\sigma) &= (\mathrm{G}(\mathrm{x},\mathrm{y},\mathrm{k}\,\sigma) - G(\mathrm{x},\mathrm{y},\sigma)) * \mathrm{I}(\mathrm{x},\mathrm{y}) \\ &= L(\mathrm{x},\mathrm{y},\mathrm{k}\,\sigma) - \mathrm{L}(\mathrm{x},\mathrm{y},\sigma) \end{aligned} \quad \textbf{(3)}$$

When detecting the extreme value in the Gaussian difference scale space (DOG Scale-space), convolution is conducted for the 26 pixels near the key point, including the 8 pixels of the same scale and near point and 18 surrounding the corresponding adjacent scale.

**Locating the feature point accurately**

Since DOG is sensitive to the noise and margin, the position and scale of the feature point shall be determined through fitting the 3D quadratic function and eliminating the margin response point with the proportion of the Hessian matrix trace and determinant, for the local extreme point in DOG scale space mentioned previously.

**Determining the main direction of the feature point**

Suppose the feature point is $x_0 = (\mathrm{x}_0, \mathrm{y}_0, \sigma)$, the neighboring window shall be made according to the size of the 2D discrete Gaussian function $G = e^{(-(\mathrm{x}^2+\mathrm{y}^2)/2(1.5\sigma)^2)}$. The main direction of the feature point can be calculated according to the module value of the gradient direction of each pixel, as shown in equation (4).

$$m(\mathrm{x},\mathrm{y}) = \sqrt{(\mathrm{L}(\mathrm{x}+1,\mathrm{y}) - \mathrm{L}(\mathrm{x}-1,\mathrm{y}))^2 + (\mathrm{L}(\mathrm{x},\mathrm{y}+1) - \mathrm{L}(\mathrm{x},\mathrm{y}-1))^2}$$
$$\vartheta(\mathrm{x},\mathrm{y}) = \mathrm{arctg}((\mathrm{L}(\mathrm{x},\mathrm{y}+1) - \mathrm{L}(\mathrm{x},\mathrm{y}-1)) / (\mathrm{L}(\mathrm{x}+1,\mathrm{y}) - \mathrm{L}(\mathrm{x}-1,\mathrm{y}))) \quad \textbf{(4)}$$

n which the scale of L is the scale of each feature point, $\vartheta$ and $m$ is the direction and module of the pixel gradient.

**Generating the description of feature point**

8*8 sampling window is taken with the feature point as the center. The center is the position of the current feature point, with each small patch representing the pixel of each feature point. The gradient module and direction of each pixel shall be worked out for the weighted operation. With histogram statistic method, the gradient histogram in eight directions shall be calculated for each 4*4 patch in the sampling window. In this way, each feature point can be represented by 128-dimension vector.

**Selection of color model**

The common color model manly consists of RGB, CMYK,, HSV, HIS and YIQ.

RGB color model mainly produce tertiary color with the three primary colors, R, G and B, as shown in equation (5).

$$C = R + G + B \quad \textbf{(5)}$$

RGB color model is widely applied in image acquisition device, such as the displayer, projector, scanner, digital camera, etc. as the most common color model.

CMYK color model mainly applies the superimposition of different branch area rates of C, M, Y and K printing ink to express colorful color and order, and it is mainly applied in printing industry.

HSV model: it mainly describes the color with Hue, Saturation and Value.

HIS model mainly starts from the human vision system and describes the color with Hue, Saturation and Intensity. It conforms to the human vision system better than RGB color model. However, the transfer from RGB to HIS is in nonlinear relation, as shown in equation (6), and it is relatively large in calculation.

The transfer equation from RGB to HIS is shown as follows:

$$H = \begin{cases} \theta & G \geq B \\ 2\pi - \theta & G < B \end{cases} \quad \textbf{(6)}$$

, where $\theta = \cos^{-1}\left( \frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2 + (R-B)(G-B)}} \right)$

$$S = 1 - \frac{3\min(R,G,B)}{R+G+B}$$

$$I = \frac{R+G+B}{3}$$

In the equation (6), R, G and B stand for the three components of RGB color model, while H, S and I stand for the three components of HIS color model.

YIQ model: as the currently most frequently used video standard, and it mainly describes the color with Y, I and Q. Y is the grey level, and IQ carries information of color. Therefore, color model can distinguish the grey information from the color information. In addition, transformation between RGB and YIQ is in linear elation, see formula (7). With small calculated amount, and good clustering feature, YIQ can adapt to the sites with varying illumination intensity.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.201 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \textbf{(7)}$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & 0.956 & 0.612 \\ 1 & -0.272 & -0.647 \\ 1 & -1.106 & 1.312 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix}$$

In order to keep the invariant color of YIQ color model, namely it shall have certain robustness to the lighting variation, normalization chromaticity coordinates model is proposed, see equation (8).

$$\begin{cases} Y = \dfrac{Y}{Y+I+Q} \\ I = \dfrac{I}{Y+I+Q} \\ Q = \dfrac{Q}{Y+I+Q} \end{cases} \quad \textbf{(8)}$$

**Matching of sample image and printed image**

**Corner detection**

Beaudet operator is a signal-based operator extracting the angular point proposed by Beaudet[6].
Based on the grey scale Hessian determinant, such angular point is defined as the local maximum value of which the corner response function value is greater than certain threshold value. The CRF is shown in equation (9).

$$CRF = \det(\mathrm{H}) = \begin{vmatrix} I_{xx} & \mathrm{I}_{xy} \\ I_{xy} & \mathrm{I}_{yy} \end{vmatrix} = \left| I_{xx} I_{yy} - I_{xy}^2 \right| \quad \textbf{(9)}$$

In which, *Ixx* and *Iyy* are the second derivative of image *I* in *x* and *y* direction.

There is no need for edge extraction of Beaudet operator, and it is characterized by invariant rotation and simple calculation. Therefore, Beaudet operator will extract the angular point as the feature points to take place of the step ⑴⑵ of SIFT algorithm.

**Image matching**

After the extraction of feature point for the sample image and printed image, the distance of the two feature points shall be calculated, as shown in equation (10).

$$d = \sqrt{\sum_{i=1}^{k} (\mathrm{I}_i^{(s)} - \mathrm{I}_i^{(t)})^2} \quad \textbf{(10)}$$

$\mathrm{I}_i^{(s)}$ is the *ith* feature point of the sample image, $\mathrm{I}_i^{(t)}$ is the *ith* feature point of the printed image, *k* is the dimensionality of the feature vector. According to the YIQ color model and SIFT algorithm, after the extraction of feature point, the 128D SIFT feature vector and 3D YQ color feature vector can be obtained. Therefore, the dimension *k* of the feature vector is $k$=128+3=131. Feature point $p_{s1}$ of the sample image is taken, and the two feature points $p_{t1}, p_{t2}$ that are closest to $p_{s1}$ shall be found out in the printed image according to equation (10).

If $d_{p_{s1}p_{t1}} / d_{p_{s1}p_{t2}} < \xi$, $\xi$ is the threshold value, set as 0.46. There will not be quality defeats if it is matched successfully, or there will be quality defeats.

## RESULT AND DISSCUSS

In order to check the effectiveness of this algorithm of Color printed image defect detection, two groups of image are listed: one group is Figure 2 to Figure 4 using printed image about Lenna, the other group is Figure 5 to Figure 7 using printed image about landscape.

In Figure 2, it is the successful matching of 120 feature points extracted from the classical sample image of Lena seen Figure (2a) and qualified printed image seen Figure (2b), for the convenience of contrast illustration of the defected image. In Figure 3, it is the acquired defected image seen Figure (3b) due to the location offset in the printing process, and it is also the quality problem of printed matter. Such quality problem can also be detected. If some of the feature points of the sample image cannot be matched successfully in the printed image, it can be judged that there is quality defect in the printed image waiting for testing. Printed image with oil stains occur seen Figure (4b), and it changes the color of the pixel in this part. As a result, In Figure 4 the feature point of the sample image cannot be matched with printed matter image for testing. Therefore, the match failure of feature points determines that there are quality defects in the printed matter.

**Figure (2a). Sample image.** **Figure (2b). Qualified printed image**

**Figure 2 : Feature point matching of sample image and printed image**

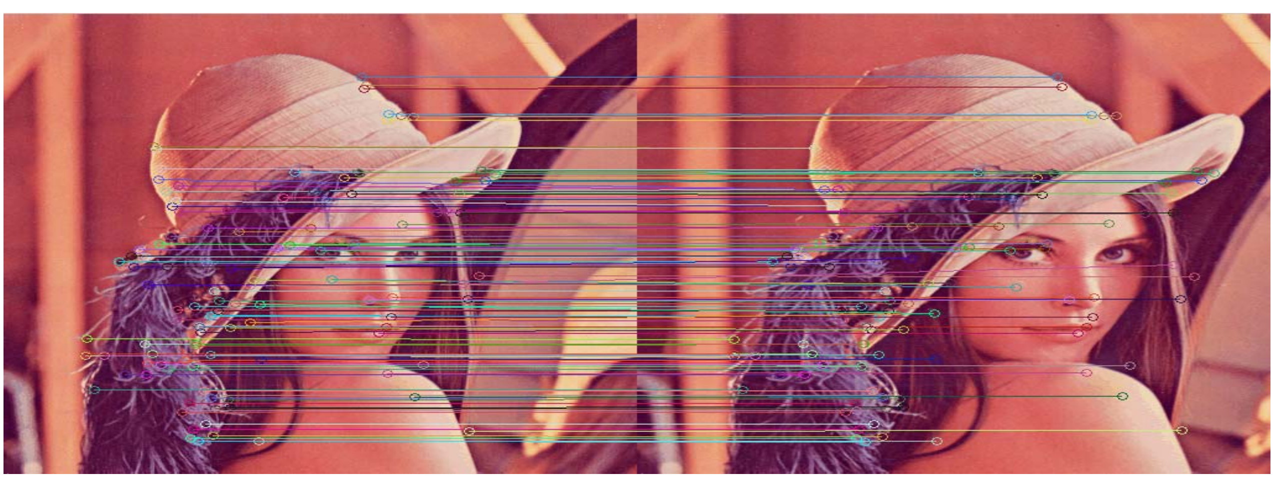

**Figure (3a). Sample image.** **Figure (3b). Printed matter image for testing.**

**Figure 3 : Feature point matching of printed image with location offset.**

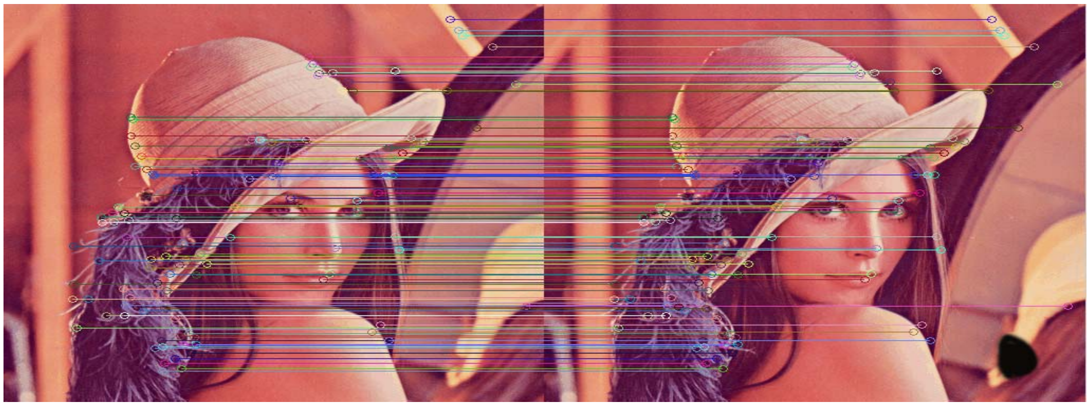

**Figure (4a). Sample image. Figure (4b). Printed matter image for testing.**

**Figure 4 : Feature point matching of printed image with oil stains.**

In Figure 5, it is the successful matching of 120 feature points extracted from the common sample image of landscape seen Figure (5a) and qualified printed image seen Figure (5b), for the convenience of contrast illustration of the defected image. In Figure (6b). region color of tree become darker in printed matter image for testing, due to ink dense packing. In Figure (6) some of the feature points of the sample image cannot be matched successfully in the pointed image, it can be judged that there is quality defect in the printed image waiting for testing. In the same way, region color of dam is slight loss of color in printed matter image for testing. Some feature points can't match between sample image and printed matter image for testing, seen Figure (7). This image is regarded as defected image.

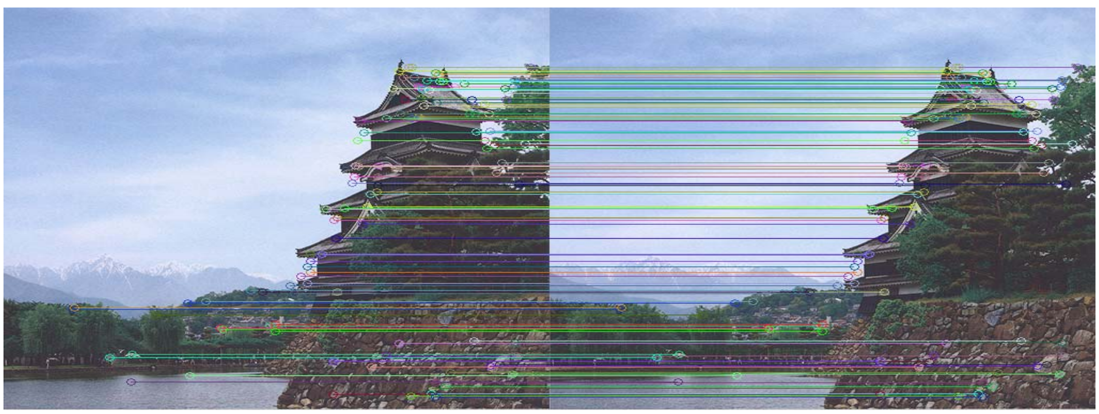

**Figure (5a). Sample image. Figure (5b). Qualified printed image.**

**Figure 5 : Feature point matching of sample image and printed image.**

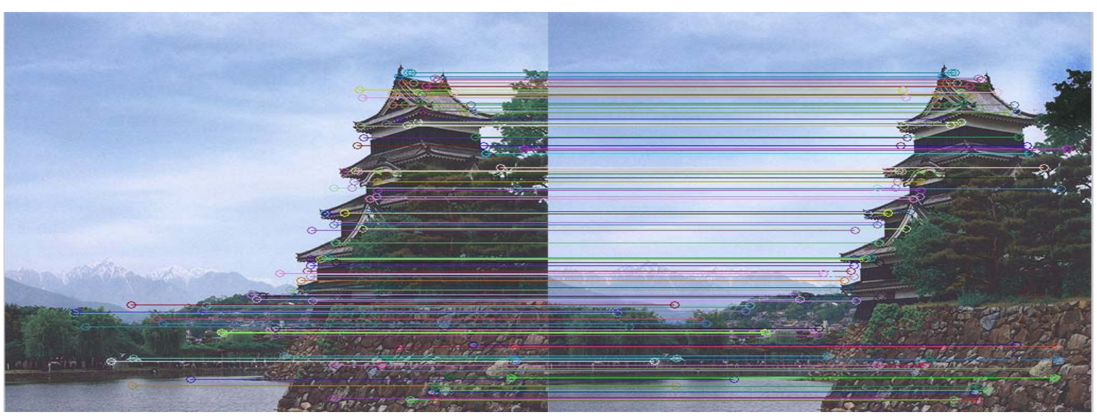

**Figure (6a). Sample image. Figure (6b). Printed matter image for testing.**

**Figure 6 : Feature point matching of printed image with color change.**

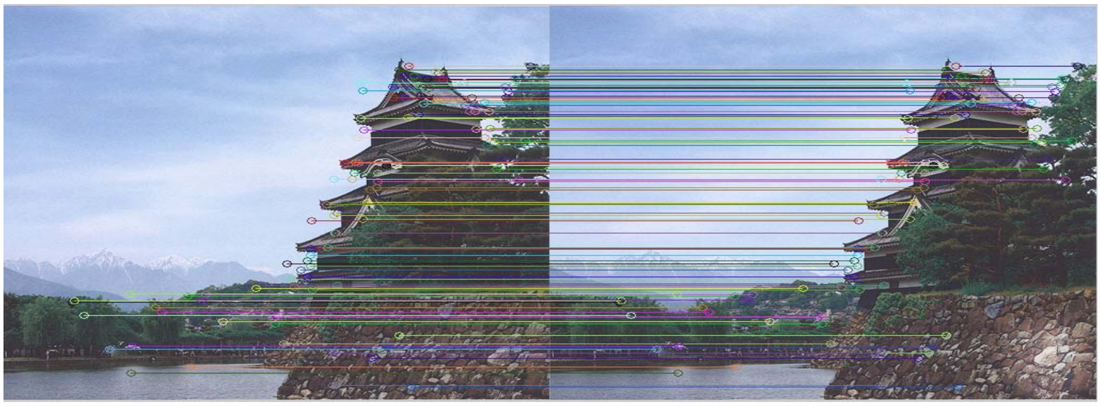

**Figure (7a). Sample image.** **Figure (7b). Printed matter image for testing.**

**Figure 7 : Feature point matching of printed image with color loss.**

## CONCLUSIONS

In this paper, color printing image defect detection algorithm based on the sift method and YIQ model is proposed. According to the experimental results, this method can detect the defects of color printing image rapidly and effectively, produced by location offset, oil stains, color change even slight color loss. In fact, this method is suited for quality monitoring of any printed matter production.

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