A FAST AND EFFICIENT METHOD FOR CHECK IMAGE QUALITY ASSESSMENT

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Abstract: With the enactment of check 21 Act, check image quality has become a critical requirement. Banks responsible for capturing check images (check truncation) have to warrant their images. With a plethora of capturing devices and outsourcing of check acquisition process, assurance of check quality becomes complex. Currently, banks deploy separate subsystem for Image Quality Analysis (IQA), which is based on defect metrics defined by Financial Services Technology Consortium (FSTC) Phase I project (Image quality and usability assurance, 2004). The problem with this approach is that IQA cannot match the scanning speed and has to be deployed as a separate process. Another problem with a predefined defect metrics is that it is dependent on check content. This paper proposes a fast and efficient method to estimate the quality and usability of check images. The method is independent of the check content or layout. IQA based on this algorithm can be deployed at the scanning stage. The checks will have a pre-printed pattern in the form of a logo. This pattern will be detected and analysed for quality and usability. The results show that our algorithm is able to sort unusable check images efficiently. In future, we plan to use this pre-printed pattern as a measure of check security.

1 INTRODUCTION

The Check Clearing for the 21st Century Act (Check 21) (Advetorial, 2005; Check Clearing for the 21st Century Act, 2003) is designed to promote innovation in the payments system and to enhance its efficiency by reducing the legal impediments to check truncation. The law facilitates check truncation by creating a new negotiable instrument called a substitute check, which permits banks to truncate original checks, to process check information electronically and to deliver substitute checks to banks that want to continue receiving paper checks.

The processing steps involved in a clearing system before Check 21 Act were tied to possession of physical checks by financial institutions. This meant physical checks had to be moved at each step in the clearing process, taking its toll on resources in terms of manpower and time (Check clearing, 2003).

While on one hand, Check 21 presents new opportunities to the banking industry to benefit from check image exchange, on the other it poses new challenges in the form of check image quality assurance and security. Banks responsible for capturing check images will have to ensure the quality of images.

FSTC (Image quality and usability assurance, 2004) had taken the check quality and assurance initiative and launched two projects - first, that identifies and defines defect metrics for quality assessment; and second, that defines a framework for assessing the usability of an image. The check quality was determined by matching 16 quantifiable parameters against predetermined thresholds. Check quality alone cannot assure the usability of a check. In the second project, it was found that out of 16 parameters the two most significant parameters that determine check usability are image ‘too light’ and ‘too dark’.

There are two problems using the FSTC approach (Wang et al., 2002). First, determination of the 16 parameters for every check is time consuming and therefore cannot be integrated with scanning. This warrants the need for a separate IQA phase. However, this increases check-processing time and requires more resources to complete the job. Second, thresholds for different defect parameters are

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generic; they do not vary for different kinds of checks. So, a check with very dark background might get rejected on the count that the image is too dark and similarly a check image devoid of background may get rejected on count of image being too light.

In this paper, we have proposed how to overcome the above-mentioned problems and also suggested a method for providing a security feature for the checks. It is achieved by designing a pattern that will be pre printed on the checks. Analysis of this pattern will be fast owing to its small size, and since characteristics of this pattern are known in advance we can define global thresholds for defect metrics. We have chosen two metrics as proposed by FSTC Check Usability report (Image quality and usability assurance, 2004), image 'too dark' and 'too light'.

Image degradation results due to various factors like the variable adjustment controls of the acquisition devices like, brightness, contrast, focusing, uneven illumination, camera calibration etc. (Smith, 1998). Figure 1 shows the changes in the gray levels that take place in the acquired image with respect to the original document.

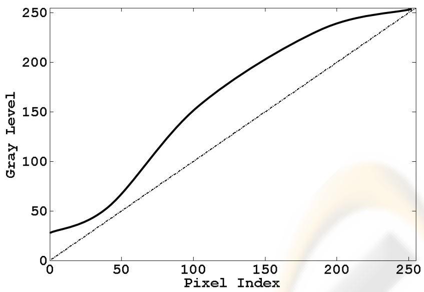


Figure 1: Straight line represents the gray levels varying linearly from 0 to 255. The curved plot represents the change in gray levels after image acquisition.

2 PROPOSED APPROACH

The proposed method is implemented in two parts. The first part enfolds the designing of the logo, which is incorporated at the printing stage. The second part pertains to the assessment of the quality parameters, which is integrated with image acquisition phase.

For an effectual solution, a number of factors need to be considered while designing the pattern. Since the overall quality assessment of the image is benchmarked using the logo, it should be printed at a convenient location on the check. An image of the check is then acquired using an image-acquisition device. The position of the logo can be determined using approaches like registration marks (Tseng and Chen, 1998; Turolla et al., 1997). The pattern or logo image should be designed in a way that it can accurately gauge the usability factors like 'too light' and 'too dark' for the image.

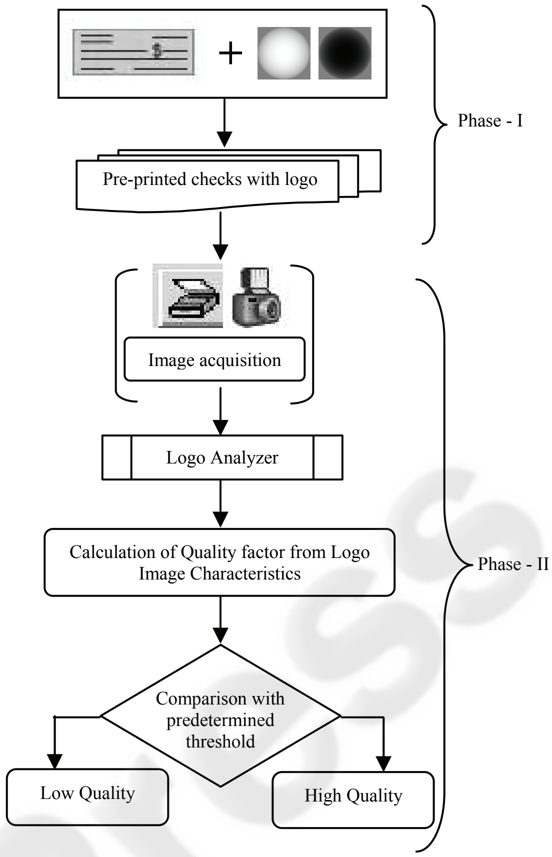


Figure 2: Block diagram of the proposed method.

Our method, shown in Figure 2, is used to correctly evaluate the quality of the acquired image by leveraging the fact that the improper brightness and contrast introduced by image acquisition device will always lead to degraded quality of the image (Lin and Chang., 1999). Our method, based on the logo image, gives a consolidated quality factor by computing different image-quality parameters (Wang et al., 2002). This quality factor is reliable (Zhang and Zhang, 2004), as it is computed by a 3-dimensional geometrical analysis and not using any semantic approach. The calculated factor is compared against a pre-calculated threshold, and the image is categorized for its usability. The value of the pre-calculated threshold is obtained on the basis of analysis of data set relative to different user environments.

2.1 PHASE–I (Logo Definition)

Two images with concentric circles of varying gray levels are printed on the check. The region outside the circumference has a uniform gray scale of 0.5 on a normalized scale of 0 to 1. The first image (Figure 3(a)) is drawn with non-linearly increasing gray levels from circumference towards center of the circle and the second image (Figure 3(b)) is drawn with non-linearly decreasing gray levels from circumference towards center of the circle. The non-linearity is chosen such that the pixel co-ordinates and the gray levels define a 3-D sphere in cartesian system. When a hypothetical sphere is drawn with same center and radius as that of circle, the gray level corresponds to the surface of the sphere from the center.

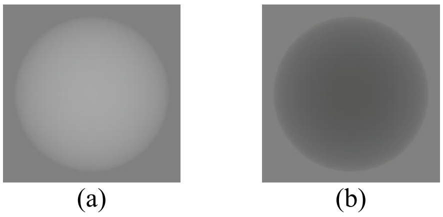


Figure 3: (a) Upper hemisphere and (b) Lower hemisphere.

The two-dimensional circular image on the paper is treated as three-dimensional hemi-sphere with x-coordinate as one dimension, y-coordinate as second dimension and the gray level at that (x, y) location as the third dimension. The two hemi-spheres when combined together form a sphere shown in Figure 4.

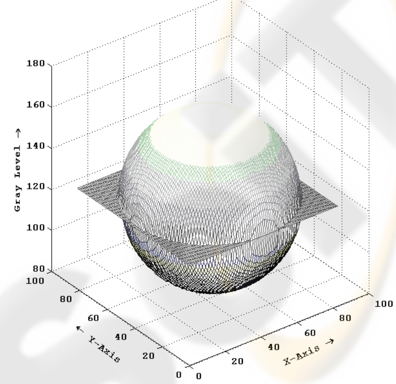


Figure 4: Three-dimensional-mesh simulation of two hemispheres.

2.2 PHASE–II (Calculation of Quality Factor)

H_u : Upper hemispherical region of the logo pattern in the check image to be analyzed.

H_l : Lower hemispherical region of the logo pattern in the check image to be analyzed.

S_o : Sphere formed by combining the upper hemispherical region and lower hemispherical region embedded in the original logo image.

η_u^+ : Count of all pixels outside the periphery of hemisphere H_u (shown as shaded area in Figure 5(a)).

η_u^- : Count of all pixels on the periphery of hemisphere H_u.

K_u^+ : Set of η_u^+ pixels in H_u

K_u^- : Set of η_u^- pixels in H_u

The value of variables η_l^+, η_l^-, K_l^+ and K_l^- for the lower hemisphere H_l can be calculated similarly.

The average gray level between the bases of H_u and H_l is determined. On check image it is the average gray level of the two regions (shown as shaded region in Figure 5(a) and (b)).

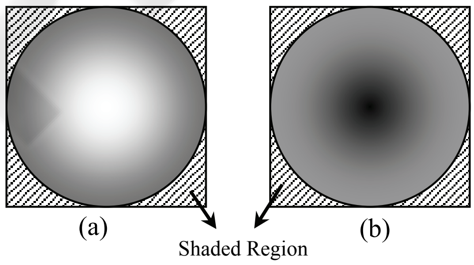


Figure 5: Schematic diagram of (a) Upper and (b) Lower hemisphere. The shaded area depicts the common base of two hemispheres, which lies outside the sphere.

Consider '*r*' as the radius of S_o and $I(x,y)$ as the gray level value at any (x, y) .

The value γ^p is computed as

$$\gamma^p = \begin{cases} I(x, y), \text{ if } (x, y) \in K_u^+ \\ 0, \text{ otherwise} \end{cases} \quad (1)$$

$$\beta_u = \sum_{i=1}^{\eta_u^+} \gamma^p(i) / \eta_u^+ \quad (2)$$

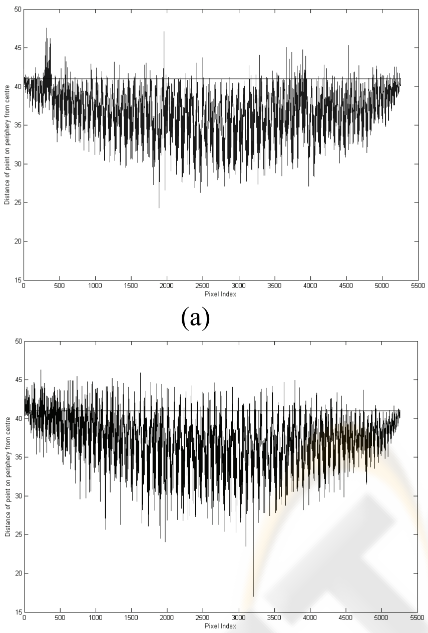
$$\beta_l = \sum_{i=1}^{\eta_l^+} \gamma^p(i) / \eta_l^+ \qquad (3)$$

where β_u is the average base value of H_u and β_l is the average base value of H_l.

The distance δ of each pixel coordinate (x, y) $\in K_u^- \bigcup K_l^-$ is calculated as.

$$\delta = \sqrt{(x-r)^2 + (y-r)^2 + (I(x,y) - mean(\beta_u, \beta_l))}$$
$$\forall (x,y) \in K_u^- \bigcup K_l^- \qquad (4)$$

The standard deviation σ of all the δ values about *'r'* gives the quality factor of the image (Ivkovic and Sankar, 2004). σ is inversely proportional to the quality factor of the image.



(a)

(b)

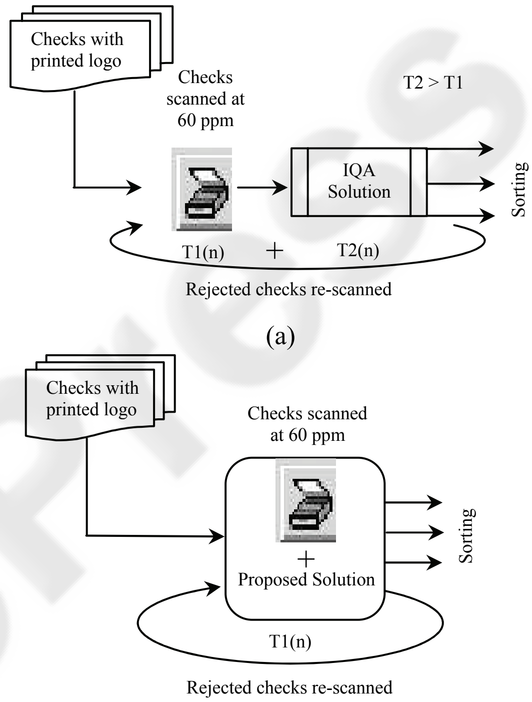
Figure 6: (a) Deviation of gray level *I(x,y)* of each pixel of H_u from *'r'*. (b) Deviation of gray level *I(x,y)* of each pixel of H_l from *'r'*.

The value of σ when compared with the pre-calculated threshold correctly identifies the image quality. The threshold is calculated by experimenting with different sets of image data. The data set should contain check documents with different backgrounds, contents and layout, and the images should be acquired using different scanners, photocopiers, etc. The calculated threshold can serve as a reference for users who do not want to re-train the system for the specific environment.

It has been observed by experimenting on different quality sets of images that σ obtained for poor-quality images is high as compared to good quality images. (Figure 6 and Table 1).

3 BENEFITS

The proposed approach offers a potential gain in the efficiency of the entire system. By integrating the proposed solution at the point of capture, a significant reduction in time can be achieved. This is shown in Figure 7.



(a)

(b)

Figure 7: (a) A schematic diagram indicating the total time taken by the existing image acquisition and quality analysis phase. (b) A schematic diagram indicating the deployment of the proposed solution at the point of capture and reduction in time.

In the experiments conducted it was found that the average time to scan a check is 1 second. When run on batch of 612 check images the IQA solution takes 0.6 seconds average to analyze the quality of one check image. For a case where 80% of checks are accepted during the first pass and 20% checks re-scanned and accepted during the second pass the total time taken to analyze the batch is {612 * (1 + 0.6) + 122 * (1 + 0.6) =} 1174.4 seconds.

On the other hand, the proposed solution (Figure 7(b)) takes average 0.18 seconds to determine the quality of a check. Hence for a batch size of 612 images and the rejection statistics as above the total time taken to analyze the batch is {612 * (1 + 0.18) + 122 * (1 + 0.18) =} 866.12 seconds. Although this time is dependent on factors like scan resolution, pixel depth and machine configuration, however, as the rejection rate during the first pass decreases the gain in the performance increases.

By analyzing just a part of the check image, the model is more efficient than other IQA solutions that analyze the entire check content. Also, the method being independent of check contents is not limited by variation in check templates.

4 EXPERIMENTAL RESULTS

In this section we present the experimental results of testing our algorithm on different check images. The data consists of checks having different content, layout and image statistics. Also the images are acquired using different image acquisition devices. Table 1 shows 15 observations from the data set of 612 images. Figure 9 shows the plot of σ calculated from images of the data set. Figure 8 shows a set of 2 logo images detected from different check images. As depicted in the corresponding 3-D simulations of the embedded pattern, the shape of the object deteriorates for bad quality images. To assess the tolerance in the change of shape of object threshold is calculated by providing supervised learning to the system on different sets of sample data. We were successfully able to classify the quality of 86% of the images in the data set based on the calculated threshold.

Table 1: Results of analysis on different image sets.

Image Index	Standard deviation, σ	Computation time (in secs.)
I_a	3.15	0.17
I_b	3.01	0.22
I_c	3.38	0.25
I_d	2.82	0.23
I_e	12.18	0.25
I_f	14.07	0.25
I_g	10.35	0.26
I_h	8.58	0.22
I_i	3.40	0.25
I_j	2.81	0.22
I_k	19.11	0.26
I_l	3.52	0.20
I_m	8.40	0.25
I_n	7.89	0.20
I_o	2.88	0.23

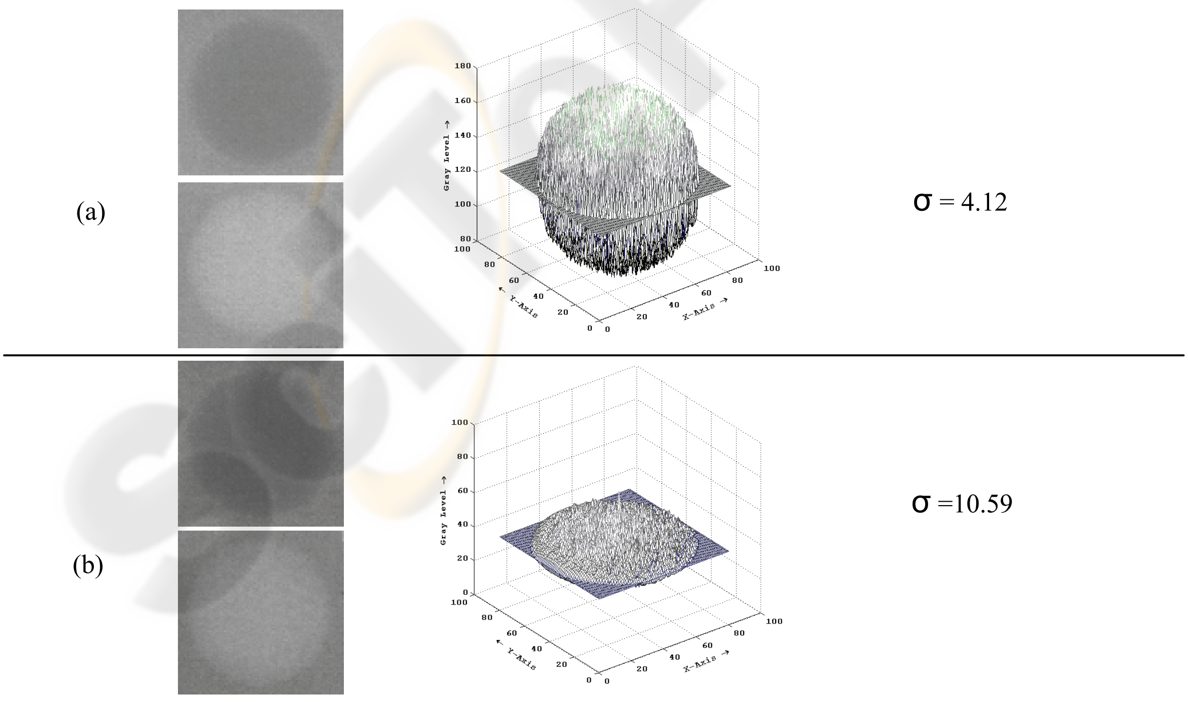


Figure 8: Logo pattern of acquired check images and the corresponding 3–D simulation of embedded object with calculated σ. As indicated above σ for good-quality images is lesser as compared to poor - quality images.

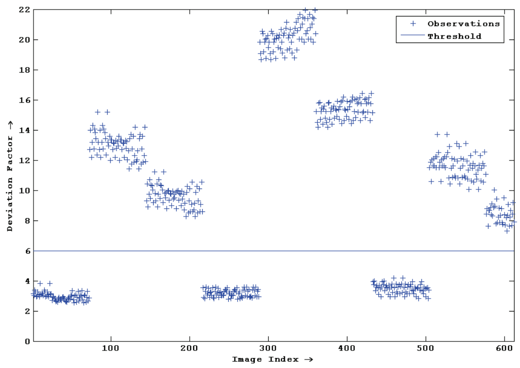


Figure 9: σ plotted for the data set of 612 images. Images with σ above the threshold have been rejected on the count of bad quality.

5 DISCUSSION AND FUTURE SCOPE

In order to perform a robust analysis of the quality level of the check image, the initial exercise to calculate the predetermined threshold should include data specific to the settings of the check scanner. Some applications may require the check documents to be scanned using a particular scanner or may require documents to be printed on a particular printer. If the model is trained in a specific environment, this will enable us to assess the quality more accurately. The more extensive the initial exercise done to find the predetermined threshold, more accurate the result is.

Proposed assessment method can be further improved by adding more features to the logo image that are sensitive to the acquisition process. Features can also be incorporated that can serve as security marks for the authorization of instruments (Wang et al., 2006). Authentication process that helps to distinguish a bona-fide copy from a forged one can be constructed around the said pattern where in a number of parameters can be extracted from multiple images of the authentic document. Individual thresholds can be calculated for each parameter and these thresholds can be compared with the parameters obtained from the document presented for certification.

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