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Extraction of Actual Faults with Adjusting the Pixel Width Parameter to Remove Undesired Noise Pixels in the Image (RPW)

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Abstract

Image Denoising, Deblurring, and Enhancement techniques are most commonly used on the images to reduce or completely remove the noise. The noisy images are not capable of perfectly using the solution of the desired problems such as object edge detection, object segmentation, and object classification. Because the edges of these objects have much bluer or more noise pixels for clearly stable detection. The main motivation of this study is to solve the problem of detection and elimination of the undesired noisy pixels on the encountered images. These noisy pixels are needed to be removed from the obtained images which are the results of throughout determined image processing steps. The main reason for this study motivation come out that to find the actual inscription fault has some noisy (undesired) pixels when extracting the true difference between the two images has been subtracted from each other. The subtracted image results are used in the inscription inspection process that controls the accuracy of the inscription quality. In the inscription inspection process, subtracted image results are used to determine the accuracy of the inscription quality. These subtracted images are formed by subtraction from each other of reference images and sample images. In these subtracted images if truly exist inscriptions faults or sometimes that could be occurred undesired noisy pixels at the same time in the subtraction process. This study focused on detecting and eliminating the undesired noisy pixels in order to reach actual inscription faults in the images. Thus, the remove pixels as width algorithm (RPW) has been developed and applied to these specified images.

Introduction

The inspection process used for printing helps control some plastic parts' inscriptions that contain printed objects such as text, characters, and symbols. These printed objects are in a variety of types and different fonts. Also, printed objects are not only belong onto plastic parts. There are many area that have the inscriptions, text, characters or symbols which are used for identify and classification of the products. Thus, nearly any industrial products have many printing characters that processed with engraving, embossed, debossed or printing techniques.

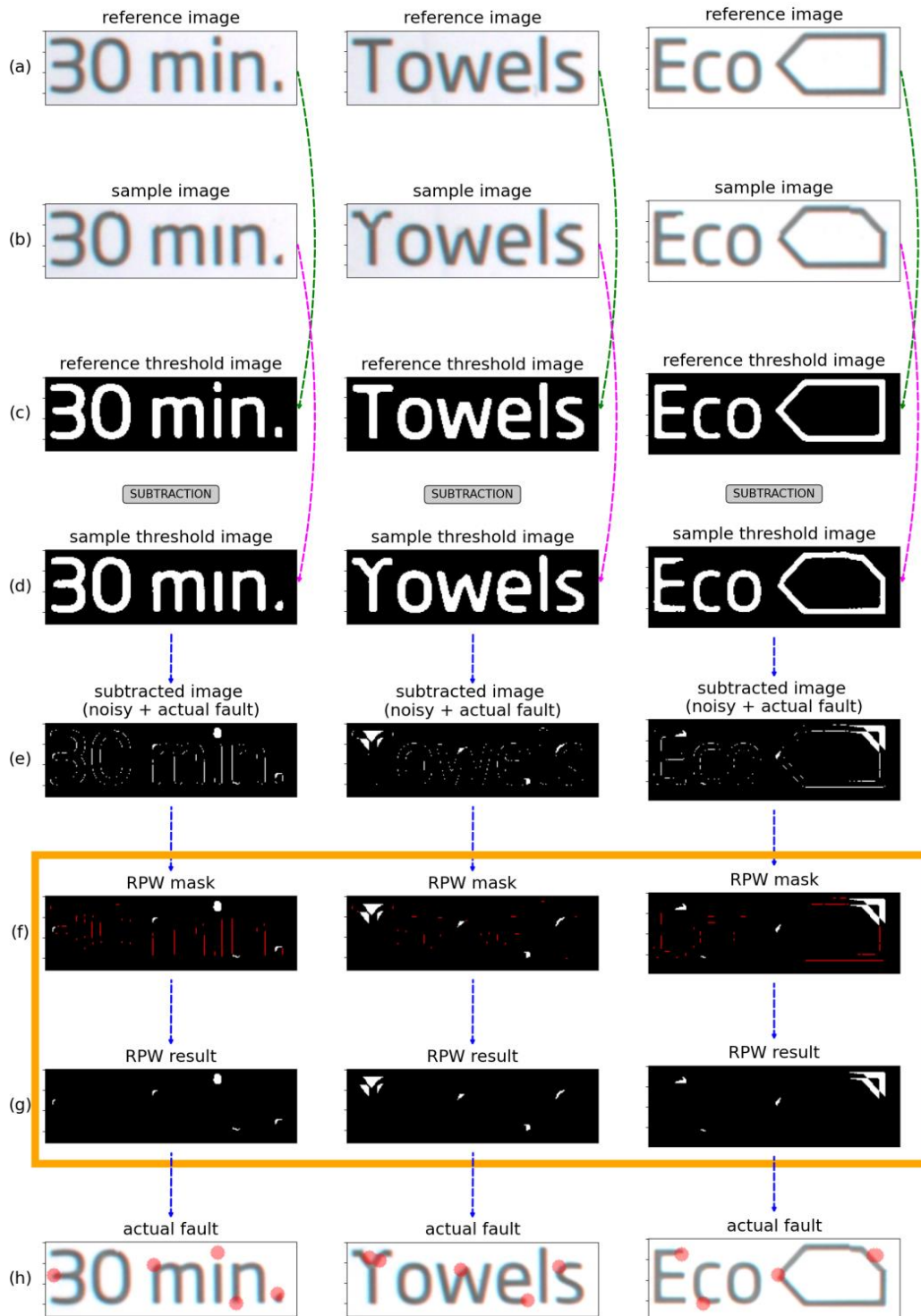


Figure 1. RPW algorithm's flow diagram is shown as initially a) reference images and b) sample images in order to compare with its related images. c) Reference and d) sample threshold images are extracted after applying many image pre-processing techniques. e) Subtracted images these are the results of subtraction process of the reference and the sample images. f) Applied RPW-mask that means detection noisy (undesired) pixels and detected pixels are pointed in red color. g) The result images of the RPW algorithms that applied on subtracted images, and also, the RPW algorithm has exposed only actual printing fault while perfectly eliminating the undesired noisy pixels. h) Exactly actual printing faults are pointed through onto sample image with small red circle

In this study, printing objects onto the plastic parts have been used as sampling to apply of RPW (Remove Pixels as Width) algorithm. These printed objects also consist of various types like text, characters, and symbols. As shown in Figure 1 (a) and (b), these objects have symbols, characters, and numbers.

Also, (see Figure 1 (a) and (b)) to show which images were used to develop the RPW algorithm, and clearly can be seen these plastic parts contain printed objects. Occasionally, undesirable inscription errors occur during the print processing steps, as shown in (see Figure 1 (b)) (Looking carefully, the difference between with Figure 1 (a) can be seen. Some characters are not sleekly printed or looks like they had deformed/decomposed).

In this study, the focus is on detecting and eliminating undesired noisy pixels in images obtained through various image processing steps. These noisy pixels often occur as a result of the subtracting process (see Figure 1 (a)) of the sample images (see Figure 1 (b)) from the reference images (see Figure 1 (a)) in the inscription inspection process, which is used to determine the accuracy of inscription quality. These subtracted images (see Figure 1 (e)) occasionally contain actual faulty pixels while also having noisy pixels as shown in (see Figure 1 (e)). Removing these noisy pixels is necessary to accurately detect any inscription faults in the images. To address this problem, the 'Remove Pixel as Width' (RPW) algorithm has been developed and applied to the specified images.

Literature Review

There are multiple techniques (Motwani, Gadiya & Motwani, 2004), (Kumar & Gupta, 2017) (Singh, Yadav & Kumar 2018) available for reducing noise in images.

Linear filters are a class of image processing techniques that use simple mathematical operations to reduce the amount of noise in an image. They are called "linear" because they preserve the linear relationships between the pixels in an image. Two commonly used linear filters are the Mean Filter (Pratt, 1978), (Gonzalez & Woods, 2018) and the Gaussian Filter (Geman & Geman, 1963), (Gonzalez & Woods, 2018). The Mean Filter, also known as the Blurring Filter, calculates the mean of the pixel values in an image and uses this value to replace the value of each pixel. This process effectively smooths out the image, reducing the amount of noise present. However, it also has the effect of blurring the edges and details of the image, so it is not suitable for all situations.

In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (b)). The Gaussian Filter is similar to the Mean Filter, but it uses a convolution smoothing filter with kernel weights drawn from a Gaussian distribution. This filter is more effective at preserving edges and details while still reducing noise, making it a popular choice for many image processing applications. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (c)).

Non-linear filters are another class of image processing techniques that do not preserve the linear relationships between the pixels in an image. They are more effective at preserving edges and details, but may not be as effective at reducing noise. One commonly used non-linear filter is the Median Filter, which replaces the value of each

pixel with the median value of the surrounding pixels (Lee, 1977). This filter is effective at removing salt and pepper noise (Erkan et. al., 2020), but may not be as effective at removing other types of noise. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (j)).

Other non-linear filters include the Kuwahara Filter (Kuwahara et. al. 1976), which uses a window of pixels to calculate the mean and variance of the image and then uses this information to smooth out the image. According to the (Kyprianidis, Kang, & Döllner, 2009) two different approach using Kuwahara Filter. One approach is The Gaussian Kuwahara filter can be considered as an extension of the classical Kuwahara filter. The Kuwahara filter divides an image into different regions according to their variances and computes the optimal statistical calculations for each region. The Gaussian Kuwahara filter adopts the same idea, but smoothed the boundaries between the regions with a Gaussian function, resulting in a smoother and more homogeneous filtering outcome. The Gaussian Kuwahara filter is particularly effective on images with severe noise and is often used in combination with other filters.

In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (g)). This filter operates slower compared to the classical Kuwahara filter, but produces higher quality results. The other approach is Mean Kuwahara filter (Guo et. al., 2018) which is a variant of the Kuwahara filter that uses the mean instead of the median to estimate the local statistics of an image.

Unlike the classical Kuwahara filter, which can produce sharp discontinuities between different regions, the Mean Kuwahara filter produces smoother transitions due to the use of mean values. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (f)). The Mean Kuwahara filter is particularly effective for images with large regions of uniform texture and is often used in combination with other filters. However, it may not perform well on images with sharp edges or small details.

Non-Local Means (NLM) Image Denoising algorithm (Buades, Coll & Morel, 2005) is a widely used image denoising algorithm that operates on the principle of finding similar patches in the image and averaging their values to obtain a denoised version of the image. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (h)). The key idea of NLM is to exploit the self-similarity property of natural images, which means that similar image patches occur frequently in different regions of the image.

The algorithm works by estimating the similarity between two patches using the Euclidean distance between their pixel values and a predefined window size. The patches with high similarity are then used to calculate the weighted average of the pixel values in the central patch. The weighting coefficients are calculated based on the similarity between the patches. This process is repeated for each pixel in the image, resulting in a denoised version of the original image.

Hough Lines algorithm, which uses the Hough Transform (Hough, 1962) to detect and remove the lines in an image. The paper presented a novel approach to detect complex shapes in images, such as lines, circles, and ellipses. The algorithm is based on the idea of representing the shapes in a parametric form and transforming the image space into a parameter space, where each shape can be represented as a point (Duda & Hart, 1972). By doing so, the problem of detecting shapes in the image is transformed into a problem of finding patterns in the parameter space. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (k)).

Other popular non-linear filters include the Bilateral Filter (Tomasi & Manduchi, 1998) is a filtering technique used in image processing that filters the image taking into account not only the pixel intensities but also the differences in pixel positions. As a result, it is an effective method for many applications such as noise reduction and sharpening. Compared to many other filtering methods, the bilateral filter creates less blurring and helps to preserve edges in images. The filtering process can be controlled by parameters such as kernel size, density variance, and spatial variance. Due to these features, bilateral filter is a widely used technique in image processing applications. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (d)).

The Box Filter (Pires, Singh & Moura, 2011) (Gonzalez & Woods, 2018), which uses a simple averaging technique to smooth out the image (see Figure 2 (e)).

The Minimum Filter (Verbeek, Vrooman & Vliet, 1988), which replaces the value of each pixel with the minimum value of the surrounding pixels. This filter performs filtering by using the smallest value of pixel intensity instead of calculating the mean or median of pixel intensities. Therefore, the minimum filter is effective in applications such as noise reduction and edge detection. It is particularly suitable for shape-based image processing methods such as morphological operations. The minimum filter, along with the maximum filter, is a basic component of max-min filters. In addition, in order to compare with the RPW algorithm, the result of this method on sample images/input images (see Figure 2 (a)) is shown in (see Figure 2 (i)).

Overall, there are a variety of techniques available for reducing noise in images, each with their own strengths and limitations. The appropriate technique will depend on the specific requirements of the application and the type of noise present in the image. The remove pixel as width (RPW) algorithm developed in this study provides a solution for detecting and eliminating undesired noisy pixels in images.

If we look at Figure 2 in which the results of the algorithm in this study are compared with the results of the similar methods mentioned above, the others methods can not capable to remove or eliminate all noisy (undesired) pixels except the Minimum filter and the Median filter. It is possible to reduce noisy pixels by using the Minimum filter (see Figure 2 (i)) and the Median filter (see Figure 2 (j)). In spite of this, those two filters were unable to keep the actual faults while eliminating noisy pixels and removed them (see Figure 2 (i) and (j)). This situation is not acceptable because of applied procedure of the inscription inspection process.

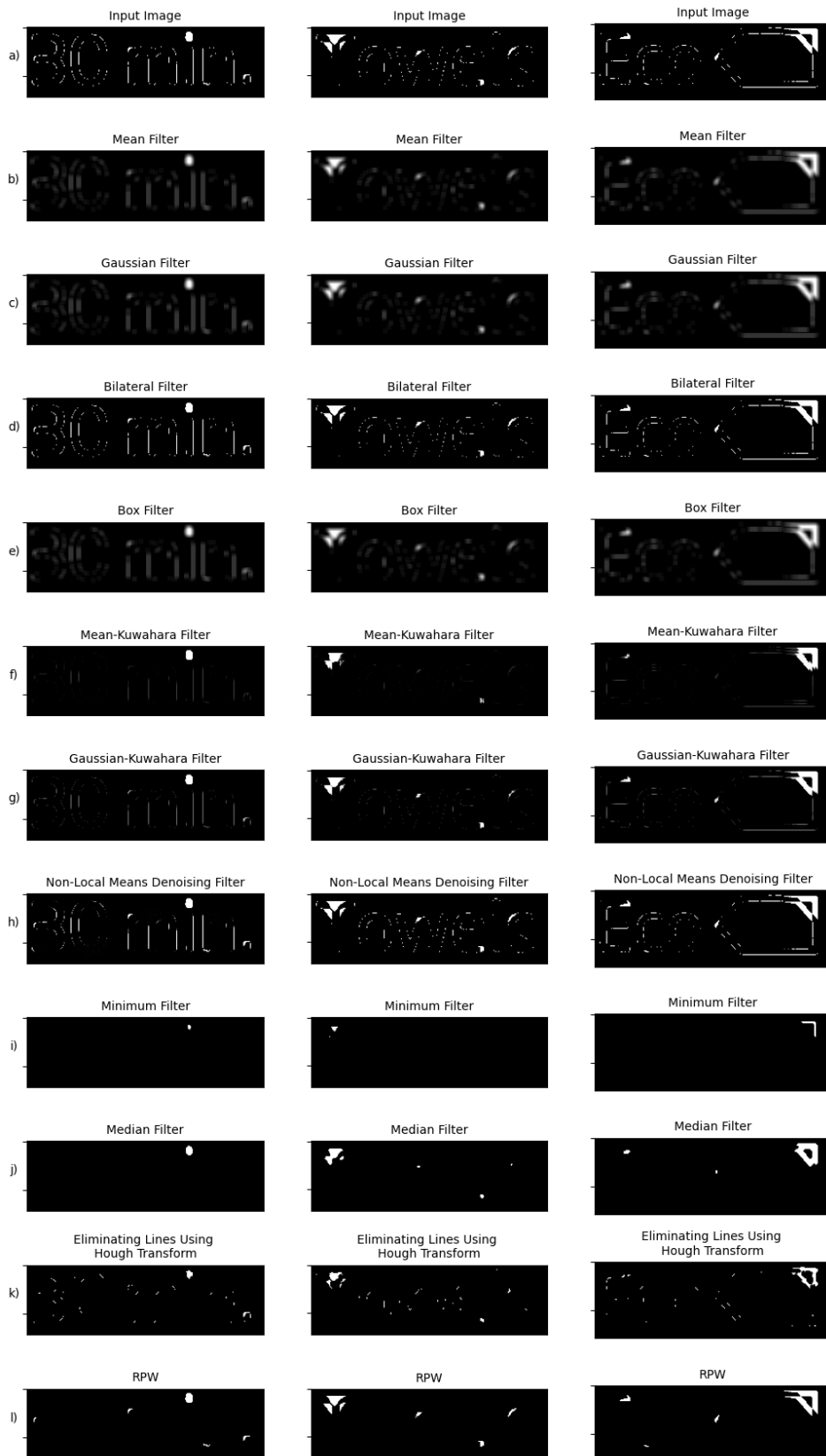


Figure 2. a) Sample images which are using as a test images to developing RPW algorithm. Comparing with some methods results can be capable are reducing noise such as; b) Mean Filter, c) Gaussian Filter, d) Bilateral Filter, e) Box Filter, f) Mean-Kuwahara Filter, g) Gaussian-Kuwahara Filter, h) Non-Local Means Denoising Filter, i) Minimum Filter, j) Median Filter, k) Hough Transform and l) the result of the RPW algorithm

Method

The Remove Pixel as Width algorithm is specially focused the mainly actual fault in the subtracted images which have noisy pixels and actual faults (see Figure 3 (a)). The RPW algorithm have two different approaches in order to make decision which one is the actual fault and which one is the noisy pixels. First approaching is using a coefficient that is positive integer number. This number determines the width of noisy pixels to be eliminated from the images.

Moreover, this coefficient is defined as k in the (see Equation 5). This coefficient is determined by the user, who can decide how wide the noisy pixels should be. Thus, the RPW algorithm is eliminate the noisy pixels less than and equal to the coefficient value. Concurrently, it detects the actual fault according to greater than the specified coefficient value (see Equation 5).

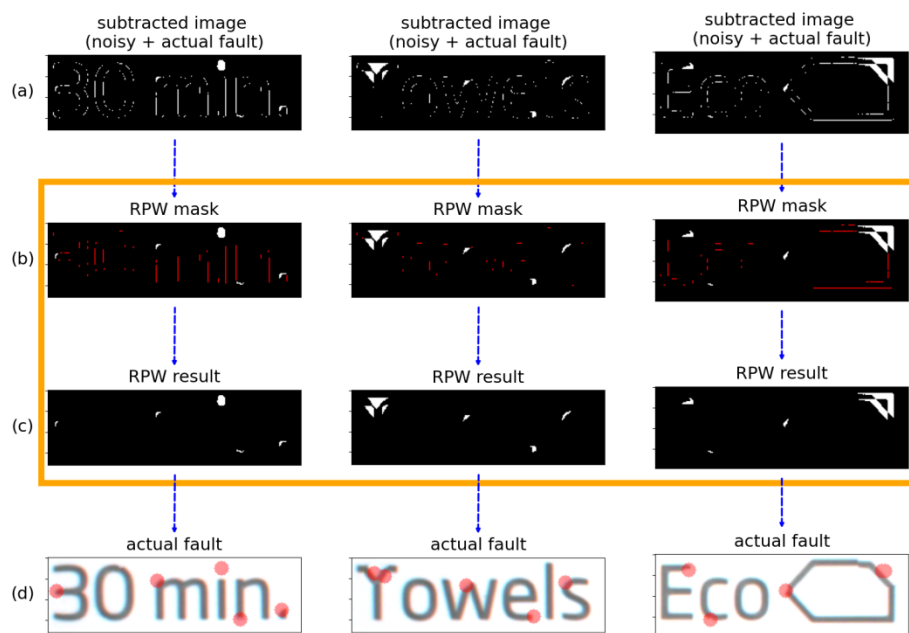


Figure 3. The RPW algorithm is applied through on the (a) subtracted images, (b) RPW mask image is detection the whole undesired noisy pixels as marked with red color and detection actual faults, (c) eliminate the detected noisy pixels and conserve the actual faults, (d) show detect the actual faults and marking them as red circles onto the sample images

The subtraction images are produced by the pre-image processing techniques shown in (see Figure 1 (c) and (d)). These techniques consist of several steps of main convectional image processing that include grayscale transform, sharpen filter, sobel edge detector and the thresholding process within settled parameters.

$$I(x) = [x_1, x_2, x_3, \dots, x_n] \quad (1)$$

$$I(y) = [y_1, y_2, y_3, \dots, y_n] \quad (2)$$

$$\Delta^x = |x_i - x_{i+1}| \quad (3)$$

$$\Delta^y = |y_i - y_{i+1}| \quad (4)$$

In equation 1, where x is an array of coordinate value on the x-axis of the subtracted image. In equation 2, where y is an array of coordinate values on the y-axis of the subtracted image. In equation 3, where Δ^x is an array that containing the absolute values of the coordinate differences between all x values. In equation 4, where Δ^y is an array that containing the absolute values of the coordinate differences between all y values.

$$RPWmask(x,y) = \begin{cases} I(x) = 255, I(y) = 255, & \text{if } \Delta^x \cup \Delta^y \leq k \\ I(x) = 0, I(y) = 0, & \text{otherwise} \end{cases} \quad (5)$$

In equation 5, where $RPWmask(x,y)$ is the result image that can able to detect noisy pixels (see Figure 3 (b)) and actual faults (see Figure 3 (b)), therefore eliminate only noisy pixels (see Figure 3 (c)). And, k is the coefficient value that provides the wide of the noisy pixels.

Results

These printing objects onto the plastic parts have been used as sampling to apply of RPW algorithm. These printed objects also consist of various types like text, characters, and symbols. The other hand, these are much more useful to candidate and clearly eliminate the undesired noisy pixels. Thus, more sample image used to apply of RPW algorithm and results of the RPW algorithm are showing in (see Figure 4 (g)).

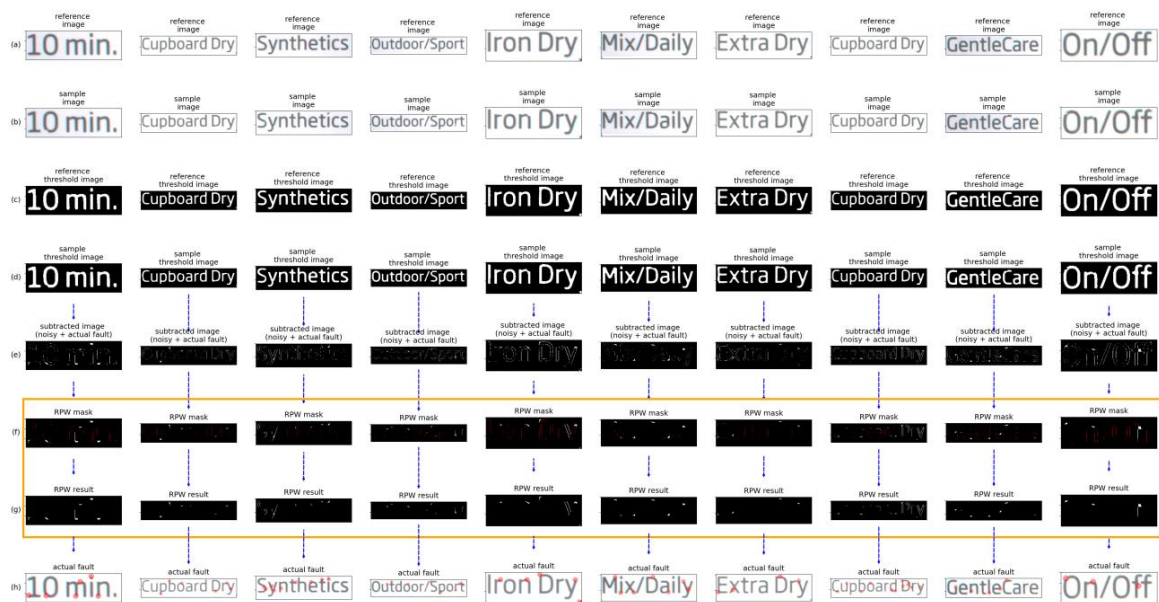


Figure 4. RPW algorithm's flow diagram is shown as initially a) reference images and b) sample images in order to compare with its related images. c) Reference and d) sample threshold images are extracted after applying many image pre-processing techniques. e) Subtracted images these are the results of subtraction process of the reference and the sample images. f) Applied RPW-mask that means detection noisy (undesired) pixels and detected pixels are pointed in red color. g) The result images of the RPW algorithms that applied on subtracted images, and also, the RPW algorithm has exposed only actual printing fault while perfectly eliminating the undesired noisy pixels. h) Exactly actual printing faults are pointed through onto sample image with small red circle

Conclusion

The subtracted images (see Figure 4 (e)), these are have both noisy pixels and actual faults. The sample images (see Figure 4 (b)) could be used for RPW algorithm and the other compared methods. Therefore, a performance metric can be read onto the (see Table 1). In Table 1, first sample image (see Figure 1 (a)) is used to compare to the other methods as Input Image.

In Table 1, where “Total Contours” express the amount of the total pixel of the input image. “Eliminated Noisy Pixels” is the number of the eliminated contours pixels. “Detected Actual Faults” is the number of the detected actual faults. And, “Preserve Actual Faults” is the number of the detected contours and carried the actual faults to the method's results. Also, “*” expression is the real numbers of the input image.

Table 1. Performance contours of total pixels in a sample image

Methods	Total Contours	Eliminated Noisy Pixels	Detected Actual Faults	Preserve Actual Faults
Input Image	114	*109	*5	N/A
Mean Filter	37	77	37	37
Gaussian Filter	37	77	37	37
Bilateral Filter	114	0	114	114
Box Filter	37	77	37	37
Mean-Kuwahara Filter	110	4	110	110
Gaussian-Kuwahara Filter	108	6	108	108
Non-Local Means Denoising	73	41	73	73
Minimum Filter	1	113	1	1
Median Filter	1	113	1	1
Hough Transform	34	80	34	34
RPW	5	109	5	5


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