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Image based automatic water meter reader

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Abstract. Water meter is used as a tool to calculate water consumption. This tool works by utilizing water flow and shows the calculation result with mechanical digit counter. Practically, in everyday use, an operator will manually check the digit counter periodically. The Operator makes logs of the number shows by water meter to know the water consumption. This manual operation is time consuming and prone to human error. Therefore, in this paper we propose an automatic water meter digit reader from digital image. The digits sequence is detected by utilizing contour information of the water meter front panel.. Then an OCR method is used to get the each digit character. The digit sequence detection is an important part of overall process. It determines the success of overall system. The result shows promising results especially in sequence detection.

1. Introduction
Water meter is commonly found in a household or industry to calculate their water consumption. It is used by the water company to know how much water consumption of every household or industry. It shows the water consumption using mechanical digit. Figure 1 shows an example of water meter. The water company checks the number shown in the water meter panel periodically, usually every month. They subtract the number in every period with the last period to know the water consumption in each period. The subtracted number is multiplied by the rates to know how much each household or industry will be charged for their water consumption. Practically, it is checked by an operator each period. The operator visits each household or industry who use the water service. The operator takes a picture of the water meter just for the documentation. They also write down the number shown in water meter. The operator reports the findings back to the water company and the water company will calculate how much each customer will be charged. All the process here is time consuming and prone to human error. Therefore if the image of water meter panel can be processed using computer to read the digit automatically it can save much work time.

(a) (b)

Figure 1. Example of Water Meter. (a) for a small household and (b) for a larger household or industry

This kind of mechanical digit is still widely used in the world, especially in developing countries. It is used not just in water meter but also for gas meter and electricity meter. We found some works which takes the topics in reading the mechanical digit from digital image. There is a series of publication by a group research that focusing on reading a meter counter from gas meter. The first was by Vanetti et al [1] who take the reading problem from gas meter. They used a neural models for detect the location of digits as they proposed in [2]. A Support Vector Machine is used to recognize each digit character. The overall accuracy is good but the complexity of the calculation is high. The example of digit counter that are shown in the test images have different background color and contrast with the panel background. It really helps in detecting the sequence digit area. Gallo et al [3] proposed an angle invariant gas meter reading. It is focused on reading the gas meter digit sequence form images that is taken not perpendicular to the panel. They used region-based algorithm and multi-layer perceptron are utilized to localize the digit area. It produced good result, even in degraded images. But, they use the red area of the digit sequence to detect the sequence location. It cannot be used in general meter digit because it utilized the specific color in the digit sequence. There are some researches about text detection and recognition in literature [4,5] but almost all of them are focusing in detecting text in natural scene and video [6-9]. There is also a focus in detecting license plate from vehicles which have closer characteristics with meter counter in term of shape and specific text location [10-13]. However, characters from digit counter have special characteristic which is different from license plate or text in natural scene. It is always has a boundary in each digit / character because of the effect of counter mechanics system. The mechanics system also makes the digit does not always appear in full or complete form. It makes the reading is difficult. From the previous research by Vanetti et al.[1] and Gallo et al.[3], there are some problems that need to be solved to improve the accuracy, such as the use of specific color to detect the sequence. Therefore, in this research we propose a method for reading an automatic meter reader from image. We propose an algorithm which utilize the moment and contour properties to detect the sequence. A series of image enhancement algorithms is also proposed to make the image easier to be read by an OCR. After enhancement and localization of the image, an OCR is used to read the text from the localized digit sequence.

The paper is organized as follows. The section 1 is talked about introduction to this research. Section 2 contains the proposed method in detail. Results and discussion are presented in Section 3. Section 4 concludes the results.

2. Research Method

The data from this research is taken using mobile phone camera. The use of mobile phone camera is chosen for a better implementation in the future. The example of water meter images that are collected and taken using mobile phone camera is shown in Figure 1. The image data are cropped manually to be square in size. The selected size is 512 x 512 pixels.

The proposed method is shown in Figure 2. The first process is converting input image from color image into grayscale image. After convert to grayscale, the image is transformed into frequency domain to perform Homomorphic Filtering. Figure 3 shows the detail process of homomorphic filtering. The homomorphic filtering is a series of process of filtering an image in frequency domain. Therefore the image is transformed into frequency domain using 2 dimensional Fourier Transform. But, before the image is transformed into frequency domain, the logarithm process is applied to the image. In frequency domain, the frequency spectrum is filtered using Butterworth filter,

$$butterworth(x, y) = 1 - \left((gH - gL) \times \frac{1}{1+\left(\frac{D_0}{dist}\right)^{2\times n}} + gL \right),$$

and

$$dist = \sqrt{\left(x - \frac{w}{2}\right)^2 + \left(y - \frac{h}{2}\right)^2},$$

where x and y are the spatial coordinate, gH and gLare the variable to adjust the high and low slope of the filter, w and h are the width and height of the filter, D0 is the distance of first cut off from the center, and n is the number of order . Then, the filtered spectrum is transformed back to spatial domain. An exponential process is done to the output image as the inverse of logarithm process in the beginning. The homomorphic filtering is useful to uniform the intensity value [14]. The non-uniform intensity value in an image occurs because the image is taken on non-uniform exposure and it is common in a real-world image.

The process after homomorphic filtering is Morphology Tophat. This is a morphological process that performssubtraction between original greyscale image with the result of morphological opening of the image. Top hat process is followed by Otsu Binarization [15]. The binarization process produces a black and white image which contains a candidate of foreground and background area. In this case, the candidate of foreground area is expected to be the digit sequence area. A morphological closing is applied to fill any background area inside a foreground area. This process produces some candidates of digit sequences.

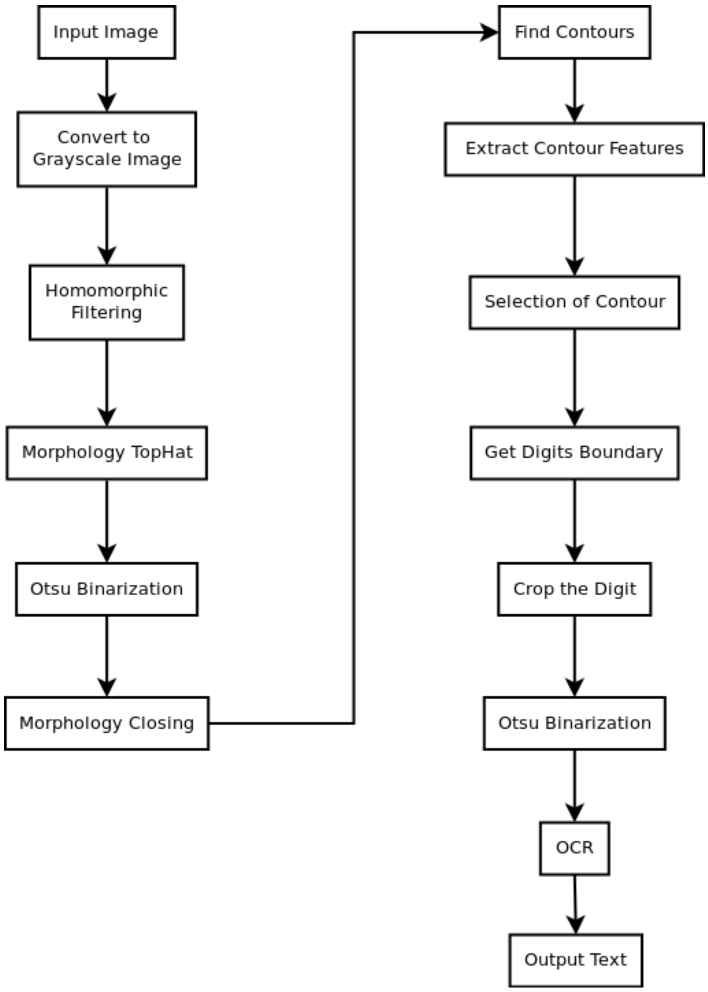

Figure 2. The Proposed Method for Reading Digits.

Figure 3. Homomorphic Filtering.

The next process, the contours of each candidate is extracted and some of the features from the contour are calculated. The features are original area, maximum rectangle area, hull area, aspect ratio, ratio of original area to maximum rectangle area, and ratio of original area to hull area. With all the features above, the right area of digit sequence is selected. After the digit area is known, the area is cropped and binarized using Otsu binarization. Then, the digits are read from binary image using an OCR.

3. Results and Discussion

The results of every step on Section 3 are presented here and it is followed by the discussion of the results. The first step is crop image into rectangle. Figure 4 shows the result of cropped image. This process is done manually. We need the sequence of digit to be horizontally aligned. The proposed method needs the sequence to be horizontally aligned because it detects the sequence from the contour properties. The property values will be different if the sequence digit is rotated. It will lead to false detection.

Then, the cropped image is converted to gray scale image to simplify the data for processing as shows in Figure 5. The greyscale image is filtered using Homomorphic filtering. In this study the value of the variables are as follows: $gH = 2$, $gL = 0.01$, $n = 1$, and $D0 = 10$. The lower the gL and the higher the gH it will gives more washed out image. The homomorphic filtering is important to make the intensity uniform. Figure 6 shows the output of homomorphic filtering.

The output image from homomorphic is processed using Top Hat. In this study we use a 3×9 kernel with all the values of the kernel are 1. Figure 7 shows the result of this process. The kernel makes the horizontal area highlighted. The higher the width of the kernel, the more horizontal area is highlighted.

Then, the output of Top Hat process is binarized using Otsu binarization. This process brings the highlighted area become a foreground and the other area become background as shown in Figure 8. The next process is morphology closing to close all background area inside a foreground area. This process is also using 3×9 kernel to make the closing process looks for horizontal area since the binary sequence is in horizontal order. Figure 9 shows the result of this process.

Each of the blob area after morphology close process is treated as a candidate of the binary sequence. Therefore, we calculate the feature from each blob. In this study, we employ a condition to filter all the blob area. The size of the blob must be more than 500 pixels, with the ratio of the area to the maximum rectangle bounding box is more than 0.5. This to ensure the blob is a rectangle. The third condition is the blob area bounding box must have width at least twice to the high. From all these conditions, the method can give more selective blob to be sequence candidate. However, the blob will still show false candidate such as the area of another text like the brand of water meter.

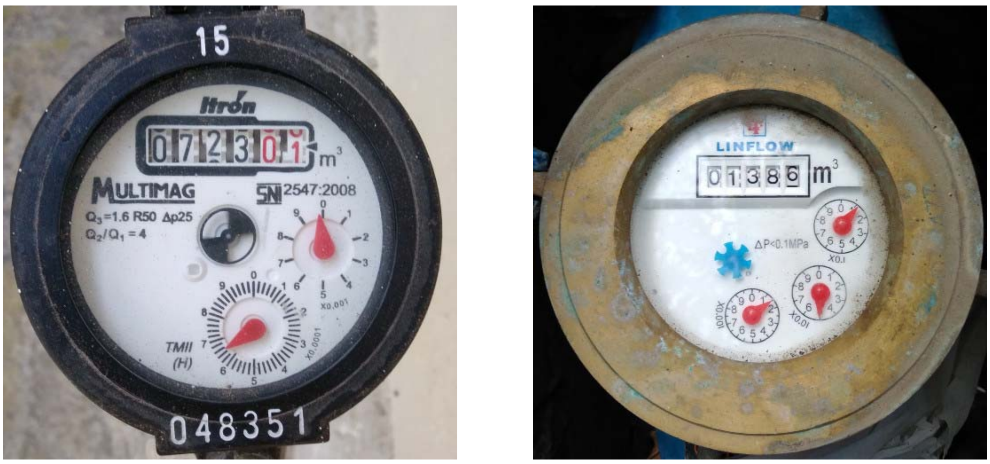

Figure 4. Cropped Image

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Figure 5. Greyscale Image.

Figure 6. Output of Homomorphic Filtering.

Figure 7. The Output of Top Hat Morphology Process.

Figure 8. The Output of Otsu Binarization.

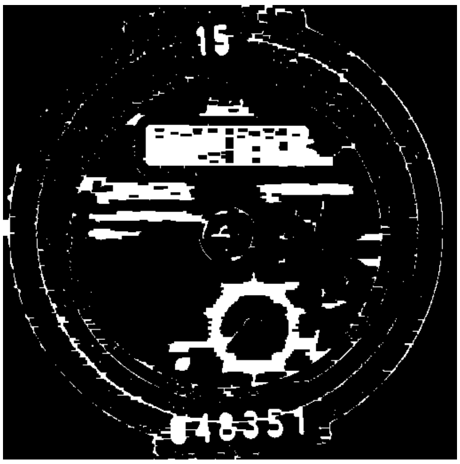

Figure 9. The Output of Morphology Closing.

Figure 10. Output of Homomorphic Filtering.

Figure 11. The Result of Binarized Digit Sequence.

Selection of the right blob is done by find the maximum solidity of the area. The solidity feature is calculated from the ratio of blob area to hull area. The maximum solidity area will give the right area of binary sequence since it is always has the maximum solidity due to the size and it has rectangle shape. Figure 10 shows the result of selected blob area. From the selected blob area, we calculate the maximum bounding box and crop the original image in the selected area. The cropped image is a binary sequence. This area isbinarized once more using otsubinarization process and the result is shown in Figure 11.
The binarized sequence then processed using OCR to read the digit. However, because the digit is still has much noise the OCR result is still not good. There are a lot of improvements needed to continue this work in future. First a finer bounding box area is needed to get the right part of digit sequence from the selected blob area. From Figure 9 we can see that the bottom right area is longer part than the upper right. It is because of the m3 sign. The maximum bounding box includes this part because it is connected to the blob area. Each single area of digit needs to be segmented to help the OCR reads the digit more precisely.

4. Conclusion
In this study, a method to read a sequence digit from water meter is presented. It contains a series of procedures from homomorphic filtering enhance the input image, a morphology process to highlight the important feature, and a selection of features using contour properties. These processes give the location of digit sequence. An OCR is employed to read the digit from selected area. The result shows a promising result which can be improved in future works.

5. Acknowledgements
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