KWh-meter Number Recognition using Normalized Cross-Correlation Technique

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Abstract. Electricity demand has become a major requirement for modern society. Many complaints forwarded by the customer's electrical system is recording kWh-meter that sometimes less accurate. This study aims to design an application that can detect the number shown on the kWh-meter automatically, to then be sent by the registrar to the office in a text format.

Process starting from the introduction of image acquisition, image conversion into grayscale format, thresholding, cropping, normalization, segmentation, template matching, and identification of patterns of numbers. System implementation using Microsoft Visual C++ 2012 with OpenCV 2.4.6.

Testing the accuracy of the resulting application includes image recognition rate, which compares the process of automatically and manually. From the experimental results, the average recognition error is 20.7%, hence the accuracy of recognition using this technique is 79.3%.

Keywords: *kWh-meter. Number Recognition, Normalized Cross-Correlation Technique*

1 Introduction

Along with the advanced of technology and the increasing of modern life, the demand of electricity has become a major requirement for the community in general. To meet to those the electricity needs, society subscribe to the State Electricity Company (Perusahaan Listrik Negara / PLN) as the main supplier of electricity in Indonesia. Every month PLN officer will record the power consumption used by the consumer through the kWh-meters (Figure 1).

Figure 1 kWh-meter

Customer complaints against kWh-meter recording in the case of swelling electricity bill [1]. This is due to the registrar who is anemployee of PLN partner companies do not record precisely based on thecustomers kWh-meter directly, but merely just by estimating the amount of power consumption.
A widely used tool in the process of the electrical power consumption recording based on the numbers listed on the kWh-meter is a Portable Data Terminal (PDT). In addition to PDT, mobile phones are also used by the registrar to take picture of the kWh - meter customer data [2]. KWh - meter recording results generated by this phone will be sent by the kWh - meter registrar via online to the PLN branch office. This research developed an application that can recognize patterns of numbers kWh - meter readings by camera, so that it can be sent to the office not in the form of image files, but it is in the form of text files, to improve the efficiency of data transmission. Template matching algorithm, which is a simple and widely used method to recognize patterns, will be used to recognize digit pattern. In the implementation of this method, there must be a model that will be used as a template for comparison on the basis of data such as shape, size, and orientation. There are several methods in template matching algorithm. This research use Normalized Cross-Correlation method [3].

Limitations of the problem in this study are:
1 . Application to be built is only for numbers pattern recognition, it does not include the recognition shipping process results.
2 . Template pattern of the numbers are 0 to 9, as the shape of the numbers on the display of kWh - meter .
3 . The image numbers pattern recognition through off line, the image captured rate resulted from kWh - meter display has been stored in a database.

2 Research Method

2.1 Previous Research Results

Pattern recognition technology can be used to identify vehicle license number [4]. Vehicle identification, specifically its license number, is very handy for parking system. Vehicle identification in present parking systems mostly use manual license number recording by a parking staff. Research conducted by Wahyono and Ernastuti intended to develop image processing methods to identify vehicle license number to replace manual identification by human. The input of the system is an image of vehicle license number captured by a digital camera.
The image was processed through some image pre-processings in order to obtain a better quality image that ready for feature extraction. Pattern recognition process was then performed to find the feature of the image. The features were in the form of vectors representing the characteristics of a letter or a number. The characteristic features were then tested for classification process using Learning Vector Quantization Artificial Neural Network method (LVQ).

Sandy also used a visual system to identify vehicle license number [5]. The process involved color image conversion to grayscale, thresholding to obtain a binary image, determining the location of vehicle license plate using horizontal projection selection method, character segmentation using vertical projection selection method, and cropping to obtain each characters of the license number.
Automatic Number Plate Recognition System (ANPR), an automatic number plate recognition system by using artificial intelligence, machine vision and artificial neural network was developed by Martinsky [6]. The research covered a wide range of mathematical principles and algorithms, which were used in the process of license plate detection, character segmentation, normalization and pattern recognition. The system performance was measured in a variety of conditions, e.g.skewed images and varied lighting conditions.

2.2 Pattern Recognition

An important issue arises in object recognition is in the search of image section which has simple form and possesses certain characteristics. For example, a front-facing face will appear as an oval shape, while in general all faces will look almost the same; dark horizontal lines on eyes and mouth, a bright vertical line along nose, and less texture on cheeks and forehead. As another example, a camera mounted on the front of a car will see stop signshaving the same shape and appearance. It states that in object recognition, a part of the image will be inspected and tested whether there is a corresponding object with similar shape and characteristics. If the size of the object is unknown, then the search needs to be done for the whole image. If the orientation of the object is unknown, it is probable to do search on all possible orientations. In general, this approach is referred to as template matching [7].

2.3 Template matching

The aim of a template matching technique is to find areas of an image that match or similar to a template image (patch). For this, two primary components are needed: a source image, in which we expect to find a match to the template image, and a template image, which will be compared to the source image.

The goal of this technique is to detect the highest matching area, by sliding the template image and comparing it against the source image. The template image is moved from one corner, horizontally and vertically, until it scans all the source image. At each position, a value is calculated to quantify how similar or how match the templateimage is to the portion the source image that is covered by the template. In this paper, we use Normalized Cross-Correlation Coefficients Function as follows [8]:

$$R(x,y) = \frac{\sum_{x',y'}(T'(x',y') \cdot I'(x+x',y+y'))}{\sqrt{\sum_{x',y'} T'(x',y')^2 \cdot \sum_{x',y'} I'(x+x',y+y')^2}} \quad (1)$$

where

$$T'(x', y') = T(x', y') - 1/(w \cdot h) \cdot \sum_{x'', y''} T(x'', y'')$$
$$I'(x + x', y + y') = I(x + x', y + y') - 1/(w \cdot h) \cdot \sum_{x'', y''} I(x + x'', y + y'') \quad (2)$$

I is the source image, *T* is the template image, *R* is a matrix containing the match value for each location of *T* over *I*

2.4 System Design

KWh-meter digit recognition system consists of two phases, namely template image generation phase and recognition phase as shown in Figure 1. In template image generation phase, individual digit images are extracted from the kWh-meter digit captured using camera, and then manually labeled according to the value of the digit and saved into template database. Furthermore, the templates will be used for comparison in recognition phase utilizing Template Matching method.

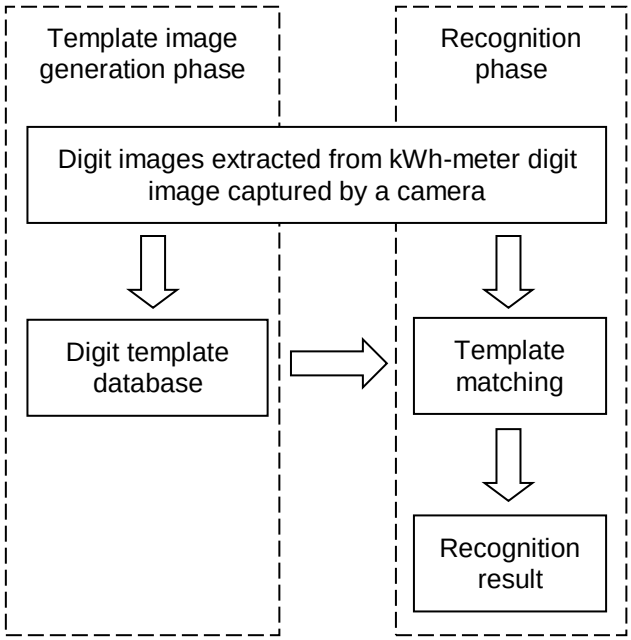

Figure 2 Block diagram of the kWh-meter digit recognition system.

The equipments used in this research are:

a. Computer: AMD Dual Core C60 processor, 2GB RAM, 320 GB harddisk
b. 5 MP 2592 x 1936 pixels digital camera
c. Delevopment software:
    1. Microsoft Visual C++ 2012
    2. OpenCV 2.4.6
d. Digit template image database obtained from the image captured from the kWhmeter

3 Results and Analysis

3.1 Digit image extraction

In this riset, we developed a technique to extract individual digit images from the kWh-meter image taken using a digital camera. Figure 2 shows the flowchart of the technique.

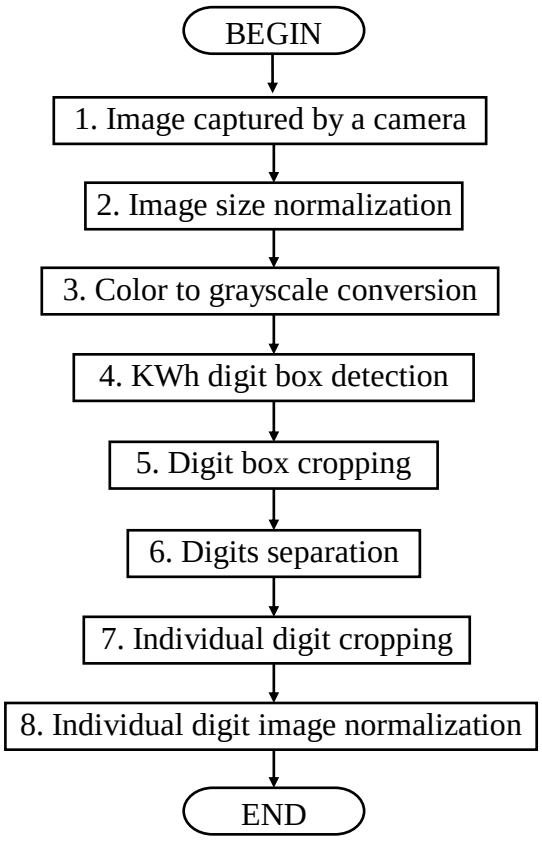

Figure 3 Type *Figure* in style box. The caption should be typed in lower case. Choose *center* if the caption fit on one line.

Detailed step-by-step explanation of the extraction process are as follows:

1. From this step, an image is obtained whose size depends on the resolution of the camera.
2. Standardization or normalization of image size, where the image is set to be 400 pixels wide, while its height is adjusted by maintaining the aspect ratio of the camera, hence image distortion can be avoided.
3. The RGB color image taken from the camera is converted into grayscale format to simplify the process.
4. A black box containing kWh-meter digit is then detected in the grayscale image by utilizing adaptive image thresholding
5. The image are then cropped on the kWh-meter digit box border.

6. The kWh-meter digit box are standardized, means that the digits inside the box have certain size and position, hence the individual digits can be localized and segmented according to the standard.
7. After the border of each individual digits are obtained from the previous steps, cropping is performed to produce 5 separated digit images.
8. The size of those 5 individual digit images are normalized to prepare them for template matching algorithm.

3.2 Result of the Template Image Generation Phase

In the template image generation phase, several captured images consisting complete combination of numbers, from 0 to 9, are selected and underwent digit extraction process. Furthermore, 20 individual digit images are chosen, comprising 2 images for each number 0 to 9.

3.3 Result of the Recognition Phase

There are images that comply with the requirement, that is all part of the black box containing kWh-meter digits should be inside the region of interest hence it will not be truncated in step 3 of the extraction process. But some images that are obtainded from improper camera shooting so that some part of the kWh-meter digit box are outside of the region of interest. These images are not well enough for recognition. Figure 3 shows the screen capture of the application.

Figure 4 Screen Capture.

(a) cropped and normalized grayscale image

(b) digit template images

(c) result of kWh-meter digit box detection

(d) result of digits separation

(e) digit image normalization

The result of digit recognition using template matching method for 30 samples are given in Table 1. The error in the fourth column is defined as the number of digits incorrectly recognized by the system.

Table 1 Result of the Experiment

No	Real Number	Recognition Result	Error	% Error
1.	14470	14470	0	0
2.	14494	14494	0	0
3.	14507	14501	1	20
4.	14531	14531	0	0
5.	14583	14589	1	20
6.	14799	14789	1	20
7.	14465	14466	1	20
8.	14470	14479	1	20
9.	14507	14501	1	20
10.	14470	14470	0	0
11.	14494	14494	0	0
12.	14507	14537	1	20
13.	14531	14551	1	20
14.	14789	14783	1	20
15.	14793	14793	0	0
16.	14799	14793	1	20
17.	14802	14403	2	40
18.	14805	14405	1	20
19.	14808	14405	2	40
20.	14812	14811	1	20
21.	14819	14619	1	20
22.	14825	14835	1	20
23.	14826	14886	1	20
24.	14885	14888	1	20
25.	14891	09878	4	80
26.	14909	14404	3	60
27.	14926	14536	2	40

28.	15010	14010	1	20
29.	14470	14470	0	0
30.	14787	14767	1	20
			Average	20,7

The experimental results have an average error of 20.7%, therefore the accuracy of this technique is 79.3%. Possible sources of the errors are identified as follows:

1. Unfocused image acquisition using digital camera.
2. The kWh-meters used by PLN have analog display, which is mechanical displays that rotate from one number to the higher number as it measures electrical usage of the customer. Image capture during this transition causes error in recognition process since no template in the database will match with extracted image of the rotating digits. Figure 4 shows the error caused by rotating digit (the rightmost digit) from number 4 to 5 which is recognized as 6.

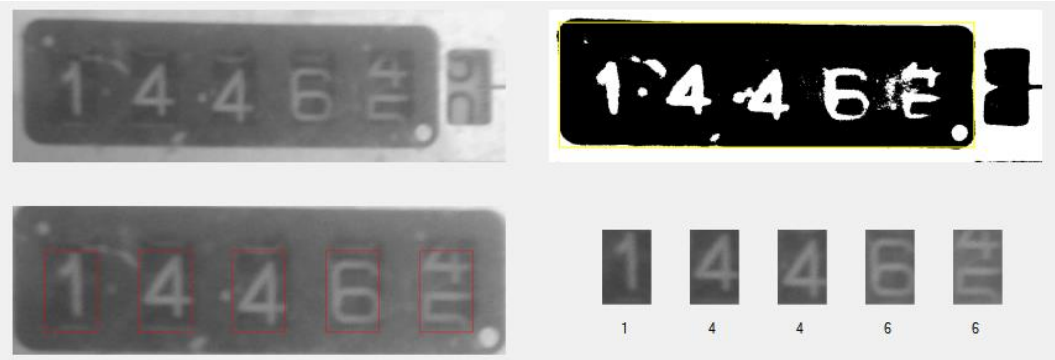

Figure 5 Error caused by rotating digit.

3. This mechanical display may also lead to misalignment, where the position of the digit might be too low as well as too high compares to the other digits. This misalignment will cause incorrect cropping of the individual digit image.
4. KWh-meter is protected inside a box attached with a glass window. The reflection of the light from the back of the operator on the window may also impact on incorrect recognition.

4 Conclusion

1. A kWh-meter number recognition system has been developed using Normalized Cross-Correlation Technique.
2. From the experimental results, the average recognition error is 20.7%, hence the accuracy of recognition using this technique is 79.3%.

3. Some possible causes of errors that have been identified are as follows:
   a. Unfocused image acquisition
   b. Image is taken during digit display rotation
   c. Misalignment of vertical position of the digit display
   d. Reflection of light from the back of the operator on the kWh-meter window.

5 Acknowledgement

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