Automatic Electricity Meter Reading Based on Image Processing

Lamiaa A. Elrefaei[*,+,1], Asrar Bajaber[*,2], Sumayyah Natheir[*,3], Nada AbuSanab[*,4], Marwa Bazi[*,5]
[*]Computer Science Department
Faculty of Computing & information Technology
King Abdulaziz University, Jeddah, Saudi Arabia
[+]Electrical Engineering Department
Faculty of Engineering, Shoubra
Benha University, Cairo, Egypt
lamiaabdalah@yahoo.com[1], u.secrets@hotmail.com[2], sumayah---@hotmail.com[3], nada_mohammed1992@hotmail.com[4], mar.bazi.mb@gmail.com[5]

***Abstract*—This paper introduces a system based on image processing to obtain efficiently and accurately reading of the electricity digital meter. In this system the back camera of the mobile phones is used to acquire the image of the electricity meter. The system then applies a sequence of image processing functions to automatically extract and recognize the digits of the meter reading image. This image goes through three main stages: preprocessing which ends up with cropping the numeric reading area, segmentation of individual digits using horizontal and vertical scanning of the cropped numeric area, and recognition of the reading by comparing each segmented digit with the digits templates. The proposed system is implemented using Android Studio software with openCV library and has been tested on 21 images of electric meters captured by Smartphone camera in Saudi Arabia, and results shows a recognition with the accuracy rate of 96,49% (per number digit) and 85.71% accuracy rate for the electricity meter readings. The proposed system will be used in the future to develop a mobile application that could be used by the electricity company employees to facilitate the reading process.**

Keywords*—*Automatic Meter Reading; Image Processing; digit segmentation; digit recognition.

I. INTRODUCTION

Electricity plays a major role in our lives. The use of electricity is increasing every day. We use it everywhere and for different purposes that we cannot imagine our lives without it. The tool used to measure the electricity consumption is Electric Meters. This work aims to facilitate the electricity meter reading mechanism for electricity company's employees in Saudi Arabia, as the existing method of manual electric meter reading is not applicable with the increasing consumption of electricity and has a lot of disadvantages: It is very tedious, time consuming, man power consuming and is prone to lot of errors.

We introduce a methodology based on image processing to obtain efficient and accurate reading of the digital electricity meters. The contribution of this work is extracting and recognizing the Arabic (Hindi) meter reading digits from electric meters in Saudi Arabia.

Based on the collected meter images, there are many versions of digital electric meter in Saudi Arabia some of them are shown in *Fig.1.* In these versions the location of the reading area is on the top of the meter, with Arabic (Hindi) numbers in some types and with English numbers in other types. In addition, they contains six digits of numbers in reading area. However, In this paper we will concentrate on the meters of type shown in *Fig.1(a)* with Arabic (Hindi) digits in the reading area.

(a) (b) (c)

Fig. 1. Some types of electric meters in Saudi Arabia

The rest of this paper is organized as follows: Section II presents the related work. The proposed system is introduced in section III, and Section IV shows the testing results of the proposed system. Finally section V presents the conclusion and future work.

II. RELATED WORK

This section presents similar researches ,the steps they followed in their systems, and the techniques they used in each step.

The authors in [1] propose a system that is composed of a camera with a timer to instruct the camera to acquire the photo of the meter reading at regular intervals of time. The system has a part for image pre-processing to convert the image to

978-1-4799-7431-3/15/$31.00 ©2015 IEEE

binary image, then adjust it by changing brightness and contrast, finally crop the numeric area. To detect the digits of the meter reading and segment them, Support Vector Machine learning algorithm is applied to the pre-processed image. Then to each of the segmented image, Support Vector Machine is applied again to recognize digits from 0 to 9. Finally, the output is sent to the Server along with other details such as Consumer name, consumer number, date/time etc. If the server didn't receive the meter reading within specified time, then server assumes camera failure and sends out service people to change the faulty camera.

In [2] the research work is about reading the values of electrical meter by using a web camera that takes a photo of the meter, recognizes the digits, and then stores the output in a text file. The overview of this research is to place a web camera connected to a laptop with 325x288 resolutions in front of the meter. The camera will take an image of the electricity meter. This image will be converted to a grayscale image, and then enhance the image by enhancement technique. In this level Adaptive Thresholding is used to convert the image to a binary image then enhance it by Morphological operations. After that, scan the image horizontally until finding a white pixel, and then segment the image by Vertical Edge Detection Algorithm (VEDA) and store the result in an array matrix. Finally, compare each segment of the image with the templates and store the result which is the meter reading in a text file.

In [3] a Remote Meter Automatic Reading Based on Computer Vision was proposed for digital instrument and for remote meter reading. The camera lens are mounted near the energy meter console, and the image videos scanned to computer with camera and image capture-board. Then image processing techniques for enhancement, sharpening, segmentation and edge detection, are applied on the sequences of the images captured. The technique used in this paper to process the image as the following: first, Image pre-treatment, which contains Spatial Calibration, Smoothing Operation, Histogram processing and Segmentation. The second is Meter Image Elements Recognition which contains Position determined of each digit and Auto recognition that use Patterns Match Algorithm to determine the value of each digit.

The Research work in [4] describes a prototype for Automatic Meter Reading (AMR) system. A camera takes the photo of meter reading and transmits it to the server PC through Zig-Bee, where that image undergoes to segmentation and recognition process, and reading the digits to be used for preparing bills. In this research the system followed these steps in image processing: Binaraization using threshold after convert the image into grayscale image, Cropping the numeric area by vertical and horizontal projection, Segmentation and recognition using Digital Recognition Algorithm.

In our work we will extract and recognize the Arabic (Hindi) meter reading digits from electric meters in Saudi Arabia on Android based smart phones in which the meter image is captured by mobile phone back camera.

III. Proposed System

The proposed system consists of three main stages of image processing as shown in *Fig. 2.* The system is implemented using Android Studio software with openCV library.

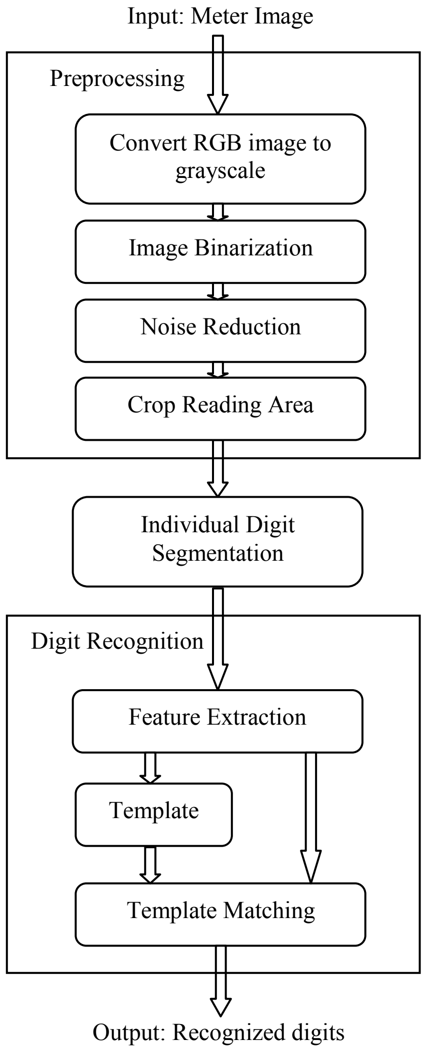


Fig. 2. The proposed system

The meter image is captured by mobile phone back camera with some constraints: the camera has to be parallel to the meter, the meter reading area has to appear in the image without shadows, part of the meter black box must appears from left and right, and the right most digit must be entirely shown and clear. *Fig. 3.(a)* shows an image of the electric meter that satisfies these constraints.

A. Preprocessing

This stage contains four steps:

- Convert RGB image to grayscale image as shown in *Fig. 3.(b)*.
- Image Binarization

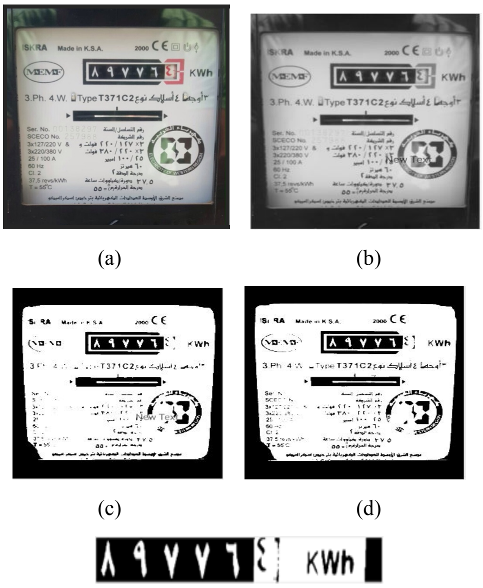
This step involves transferring an image to a black and white image as shown in *Fig. 3.(c)*, it is a fundamental step before reading area detection. In this step a threshold function was used.

- Noise Reduction

Because of the noise could appear on the image after the binarization, noise reduction algorithm must be applied to reduce the noise. We chose to apply Morphological operations as shown in *Fig. 3.(d)*.

- Crop Reading Area

In this step, the binarized image is processed to crop the part that has the meter reading only. We observed that the meter reading area is placed on the top middle of the meter image and it is inside an outer black borders and an inner white boarders. We proposed to search for the small inner white boarders around the reading area, so we scan the binarized image I, from top side starting from the middle pixel at I(Iwidth/2, 0) to find the first black pixel of the outer boarders, continue scanning to find the first white pixel of the inner boarders, and continue scanning to find a black pixel of the meter reading area say at (x,y). Then from that pixel at (x,y) we scan to the left side until we find a white pixel say at (x1,y1) and from that pixel we scan to the bottom side until we find a white pixel say at (x3,y3). After that clipping the image area starting at (x1,y1) with a height of (y3-y2) and a width of (Iwidth –x2) to get a new image contains the meter reading as shown in *Fig. 3.(e)*.



(a) (b) (c) (d) (e)

Fig. 3. Preprocessing: (a) Input Image ,(b) Grayscale Image. (c) Binarized Image, (d)Apply Morphological Operations ,(e) Cropped numeric area.

B. *Individual Digits Segmentation*

The proposed idea behind digit segmentation is to scan the cropped numeric area vertically and horizontally from left to right and produce six segmented digits [5][6]. Then resize all segmented digits in order to make them similar in size so, the recognition stage will be easier.

- Vertical Scanning

In this step we will find the first and last columns of each digit. We will scan the cropped numeric area image from the top leftmost pixel and go vertically in column, once we catch a white pixel we will save its column and call it Xl, if we did not catch a white pixel in that column we continue to search in the next column until we find it. So now we have found the first column, the vertical line from the left side of the digit. After that we are going to search for the last column, the vertical line from the right side of the digit, we will start to scan from Xl but now we will search for a black pixel. We will go through each pixel column by column, once we find a black pixel we count it, if the number of black pixels in that column is equal to the cropped numeric image height, it means we found a black vertical line, we save its column and call it Xr. If we found a white pixel in that column we leave it and move to the next line. Now the digit width is (Xr-Xl)[5][6].

- Horizontal Scanning

In this step we will find the first and last rows of each digit. We will repeat the previous steps but horizontally for every digit. To identify the top horizontal line, we scan the area between Xl and Xr from the top leftmost pixel and go in rows. Once we find a white pixel in that row we save that row and call it Yu. If we did not find a white pixel, we continue to search in the next row. We will start to scan again from Yu to identify the down horizontal line, we scan the horizontally to count the number of black pixels in that row, and if it is equal to the digit width we save that row and call it Yb. The digit height is (Yb-Yu) [5][6]. *Fig. 4* illustrates the vertical and horizontal lines.

Fig. 4. Vertical and Horizontal Scanning

Now we crop the digit starting from (X1,Y1) -where X1 and Y1 are the first white pixel dimensions as mentioned above- according to the new height and width. We repeat these steps five times to segment each of the left five digits.

It is clear in *Fig.3.(e)* that the right most digit color is different than the other five digits. We segment this digit using the same procedure but rather than searching for the white pixel we search for the black pixel. After segmenting it, we convert the black pixels to white pixels and vice versa. This will make the digit recognition easier, so we do not have to treat it using different digit recognition method. Applying these steps will produce six segmented digits as shown in *Fig.5*.

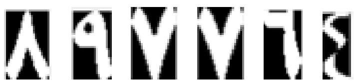


Fig. 5. The segmented digits

After segmenting the six meter reading digits, we resize the images to 32*32 pixel as shown in *Fig.6.* The size of

32*32 is selected based on experimental results that will be presented in section V.

Fig. 6. Resized segmented digits

C. Digits Recognition

The technique we used for digit recognition is based on the number of white pixels [6], for this reason all the segmented images are resized to 32x32 images to ensure that the range of the white pixels on all the digits does not exceed 1024 pixels. This stage consists of two steps, feature extraction and template matching.

- Feature Extraction

In this step, First we will take few segmented images of the meter reading digits, treat them as templates, and extract some features from them. We need one sample for each digit which means ten segmented images that represent ten different digits treated as templates. We start with the first zero digit template, divide it into four quadrants and in each quadrant we calculate the number of white pixels q1, q2, q3, and q4. We repeat these steps for the rest of nine samples. For each digit now, we have four values for the four quadrants. We save these values for further comparison [6]. *Fig.7* shows how we divided the "Thamania (8)" digit image into four quadrants. Table I shows sample of the ten digit images and four quadrants values for digits from "sifr (0)" to "tesaa (9).

Beside using template features extracted from one segmented digit, we also investigated in section V the performance of generating a template from averaging features extracted from five segmented images for each digit.

- Template Matching

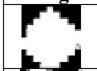
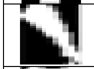
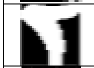
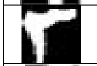
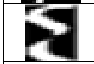
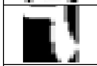
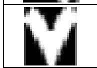
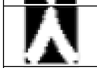
We will take the six segmented digits, divide each digit image into four quadrants and calculate the number of the white pixels in each quadrant q1, q2, q3, q4. Let's say we have the digit image X, we calculate difference values DV_i as in (1):

$$DV_i = \frac{1}{4}\left(\sum_{j=1}^{4} | q_{jX} - q_{jT} |\right), i = 0,1,2,.....,9 \quad (1)$$

Where q_{jX} and q_{jT} are the numbers of the white pixels in quadrant $j=1,2,3,4$ for the segmented digit image and the template respectively. We end up having ten DV values. The segmented digit is recognized to be digit i with the minimum DV_i value [6].

Fig. 7. Quadrants of digit "Thamania (8)"

TABLE I. EXAMPLE OF THE NUMBER OF WHITE PIXELS IN EACH QUADRANT FOR EACH DIGIT

Digit image	q1	q2	q3	q4
	207	202	233	198
	185	140	23	212
	228	166	72	119
	205	115	111	0
	174	90	173	67
	113	138	203	201
	120	158	0	193
	180	185	124	102
	115	78	179	169
	177	177	12	189

IV. RESULTS

The system is tested on 21 electricity meter images of type shown in *Fig 1.(a)*, these images were captured using the back camera of many mobile phones in outdoor environment.

Fig 8. shows some samples of the tested images and the output result from crop numeric area, digit segmentation, and digit recognition stages. The performance of the individual system stages are shown in Table II.

Table II shows that the meter reading areas are correctly cropped in 19 images from a total of 21. and a total of 114 individual digits are successfully segmented from these 19 images giving accuracy rate of 90.47% for both stages.

The 114 successfully segmented digits are used to investigate the effect of segmented digit size and the number of segmented digits used for template generation on the performance of the Digit Recognition stage, in which the recognition rate is evaluated using 32*32 and 64*64 segmented digit size with a template generated from only one segmented digit and also from averaging five segmented digits. Table III shows the results, and it is clear that we get better results (96.49% per digit recognition rate) with segmented digit size of 32*32 and generated a template from averaging features extracted from five segmented images for each digit.

Finally, Table II shows that the system correctly recognized the meter reading in 18 images giving 85.71% accuracy rate for the meter readings.

(a) (b)

Fig. 8. Samples of the system stages output: (a) Input Images ,(b) The system stages output.

TABLE II. PERFORMANCE OF THE SYSTEM STAGES

Total number of electricity meter images	Correct Crop Numeric Area	Correct Individual Digit Segmentation	Correct Reading Recognition
21	19 (90.47%)	19 (90.47%)	18 (85.71%)

TABLE III. DIGIT RECOGNITION STAGE RESULTS

Total number of input segmented digit images	Using one segmented digit for template generation		Using the average from 5 segmented digits for template generation	
	*Segmented digit size 32*32*	*Segmented digit size 64*64*	*Segmented digit size 32*32*	*Segmented digit size 64*64*
114	103 (90.35%)	94 (82.45%)	110 (96.49%)	99 (86.84%)

V. CONCLUSION AND FUTURE WORK

This paper presented an automatic electricity meter reading system based on image processing in Saudi Arabia. Results showed that the system can recognize the electric meter reading digits in three main phases of image processing with sufficient accuracy of 96,49% for each digit and the percentage accuracy of entire reading of 85.71% .

The future plan is to improve the system so that it can recognize the reading of different types of meters in Saudi Arabia, improve the system accuracy, and develop a mobile application for the electricity company employees that uses our system to facilitate the reading process. Using this application the employee just capture the electricity meter image, then the application process the image, recognize the meter reading and automatically send the reading to the company server.

REFERENCES

[1] C. Edward, *Support Vector Machine Based Automatic Electric Meter Reading System,* IEEE International Conference on Computational Intelligence and Computing Research, 2013, pp. 1-5.

[2] K. Parthiban and A. M. Palanisamy, *Reading Values in Electrical Meter Using Image Processing Techniques*, IEEE International Conference on Intelligent Interactive Systems and Assistive Technologies,Coimbatore, INDIA, 2013, pp. 1-6.

[3] S. Zhao, B. Li, J. Yuan, G. Cui, *Research on Remote Meter Automatic Reading Based on Computer Vision*, IEEE/PES Transmission and Distribution Conference, China Dec, 2005, pp. 1–4.

[4] M. Shinde and P. Kulkarni, *Reading of Energy Meter based on Image Processing Technology,* International Journal of Electronics Communication and Computer Engineering, Volume 5, Issue (4) July, Technovision-2014, pp. 1-5.

[5] R. F. Mansour, *A Robust Method for Arabic Car Plates Recognition and Matching Using Chain Code*, American Journal of Computational and Applied Mathematics 2012, 2(3): 105-111.

[6] Granger, H., Chanchad, R., & Razak, S., *License Plate Number Detection Algorithm for Qatari License Plates*, 2012, pp.1-6.