Android Application for Automating the CEB Meter Reading System

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Abstract *- Currently CEB is facing quite a lot of problems in obtaining meter reading from customers due to circumstances such as house owner is out of the house by the time the reader visits or because the readers undergo difficulties in reaching the meter due to pets of house owners such as dogs. Hence the objective of this research is to develop a system to automate the process of obtaining the meter reading to cater the identified issue. To address this matter a method inculcating an android application and an image processing techniques is proposed. So the basic idea behind the research is developing an application through which the CEB meter reading can be directly uploaded to the database by capturing an image of the household electric meter using a mobile phone. This process is divided into four steps; Android app development, web service to send the image to server, image processing and bill calculation. Image processing which is the core area of this research is carried out via MATLAB. The system is developed to suit different higher android versions starting from the android version "honeycomb". The number recognition capability of this image processing technique is tested for 110 different real samples of images obtained from phone cameras with different resolutions. Accuracy of detection of individual digits has been tested and an overall success rate of 90% is obtained.*

Keywords **–** Image Processing, Optical Character Recognition, Template Matching

I. Introduction

Presently Image processing has become a trending technology due to its enormous applications which makes human life easier. The two most popular and the oldest image recognition techniques are the barcode recognition and number detection. However unlike barcode recognition principles which is unique to its purpose, character detection can be used in various fields of application. Currently it is mostly used for vehicle license plate recognition which is a research area that has been arisen due to the growing demand of traffic and the increase in number of vehicles around the world. Vehicle chasse number recognition and library call number identification for book shelves stand among the other applications which utilize image processing for character recognition.

Even in Sri Lanka several work has been carried out to develop methods for vehicle license plate recognition incorporating image processing. However, still the use of Image processing techniques are limited only to that application considering Sri Lankan context while there exists several other fields which can use these techniques. One such example is the Ceylon Electricity Board (CEB) meter reading system. Currently, their method of obtaining meter reading is that, a meter reader visits each household, note down the reading and prepare the bill. True it is a successful method for most of their customers. Yet there are also instances where the house owner is out of house by the time the meter reader visits. According to the information received from CEB, monthly about 5% of such cases are recorded which accounts to around 250000 customers which is a huge amount.

The general principle followed by the meter reader in such situations is to create an estimated bill based on previous month's consumption. Such a reading is called an assess reading. Due to the fact that the household consumption of electricity doesn't remain the same in every month, chances are very rare that the meter reading value is the same in two consecutive months. Hence this assess reading can be either an over estimated reading or an under estimated reading. Either way it creates a problem in both customer side and the organization side. In customer's point of view an over estimated bill makes him pay more than what he has actually consumed which is unfair and on the other hand if it is an under estimated reading it is a loss to the organization based on the large supply they have already made for that month. In addition in cases where such issues has aroused CEB has instructed their customers to inform them and there need to be a revisit to rectify the issue and it is a tedious process.

Therefore as a solution to the aforementioned problem, the aim of this research is to introduce an android application through which the customer himself can send the meter reading to the CEB database. The basic idea behind this research is, the customer if he is unable to stay at home by the time the meter reader visits, he can

request this service from CEB and he can download this application from the CEB site. The user can use his smart phone and within a period of days specified by the CEB, each month, he has to open this application, capture the image through it, crop the image as instructed and press the send button so it will be received by a remote server at the CEB. The only additional requirement is that he should either have enabled his phone's data service or should be connected to Wi-Fi network because the image is sent to the remote server via internet. Within couple of minutes after sending the image he will be informed with a feedback regarding his electricity bill for the month as depicted in the figure1.

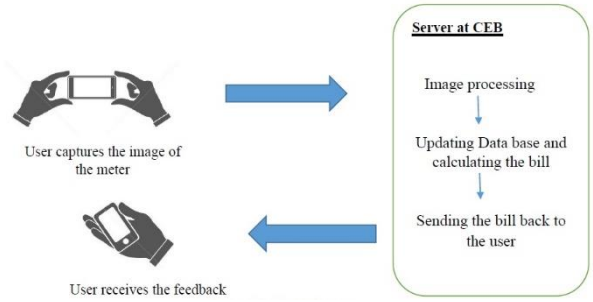

Figure 1. Proposed System

In this research the reason for moving into a solution of developing a mobile application rather than introducing adjustments to the existing meter so that directly meter reading can be updated to the CEB database without human intervention, or without suggesting to use digital meters is due to several reasons as specified below.

1. This method is cost effective. When introducing a new design for the meter, all the existing meters have to be replaced and it will generate an additional cost. Furthermore, the digital meter generally cost around Rs.13000 while the analog meter which is commonly used cost only about Rs.1500.
2. This system is easily accessible. Almost every individual today is equipped with a smart phone which is the basic need to access this system.
3. Implementation of this system is very easy. It's just a matter of downloading the application.

In this research it was identified that CEB use different meter types. However most of these meters are older versions and are being now replaced by the newer versions. Figure 2 illustrates the most widely used meter type since 2005 and statistics shows that around 25%-40% of the Sri Lankan households are equipped with this meter type and hence it is the main focus in this research.

However even after developing a method to extract the meter reading, there isn't a proper method to identify customer to update the data. There is a possibility to sync the reading with the phone number through which the image is delivered, but then the user could even capture an image from somewhere else and send. Hence as a solution for this using a barcode for customer verification is suggested. Hence, once the service is requested by the user, CEB will allocate a certain barcode to the user and it will be pasted on his electric meter in a way that it cannot

Figure 2. The meter type used

be removed from there without causing damage to the meter which accounts as a crime according to the CEB rules and regulations. Therefore security concerns are also assured in this manner while preserving a method to identify the user properly. The program development is done using Matlab version R2014a and it is recommended to use a mobile phone with the resolution equal to or more than 2.4 MP.

II. Literature Review

The most common application of image processing is character recognition. Wanniarachchi, Sonnadara & Jayananda (2007); Babu, Siva & Parasuraman (2010); Barroso, Rafael, Dagless& Bulos-Cruz (1997);Laxmi , Karan & Mahanta (2011) have developed systems for the process of vehicle license plate detection which involves character recognition. Each of the four deals with different system conditions and based on that they have utilized the most efficient method for their design considerations after analyzing the available methods for each step and some have proposed new methods as well.

Typical number identification system has three logical components, a camera, OCR software and output interface (Quadri & Asif , 2013) The image captured by the camera which is in the RGB format is rescaled to a standard size and then cropped in order to minimize the processing time in next stages and to eliminate unwanted objects (Bakar, Abdullah, Noordin, Musa & Xian , 2012). Then locating of the number plate in the image is done. Normally background colour of the number plate is concerned here. yellow pixel searching, determining the license plate byusing double edge detection technique based on colour features and also Hough transform can be used to locate the number plate. Once the RGB image is

input most systems deals with the RGB colour space directly and convert the image to gray scale while some use NTCS standard method to convert the image to gray scale (Barroso, Rafael, Dagless & Bulos-Cruz, 1997)

Next it is the edge detection where the discontinuities in the intensity are detected. There are several edge detection operators in use like Robert, Prewith, Sobel operator, canny, morphological operations followed by bounding boxes and 'feature based number plate localization', enhanced Hough Transform and line based method for localization of the number plate area etc. In case of noise filtering for enhancing the image both Gaussian filter and median filter have been utilized. Then by using a structural element small objects are removed.

Next phase is character segmentation. Widely used character segmentation techniques are static bounds, vertical projection and connected components (Babu, Siva & Parasuraman, 2010). However to use these techniques there should be a fixed no. of characters in the subject. But sometimes the number of characters may vary. Hence a different 4 step process for character segmentation which is the 'peak-to- valley' method by Lu is proposed and as another method to overcome this feature extraction using wavelet methods is used (Laxmi , Karan & Mahanta,2011). Also bounding box technique is common where image is scanned row wise once from top to bottom and bottom to top. Then continues to column wise as well. However feature vector extraction and mathematical morphology, and Markov Random Field (MRFs) are also can be used as segmentation techniques (Shah, Karamchandani, Nadkar, Gulechcha, Koli & Lad, 2009).

Final phase is character recognition and it can be done by using Optical Character Recognition (OCR), Radial Basis Function (RBF), Probabilistic Neural Network (PNN) and Fuzzy system. OCR is preferred due to its high accuracy compared to other techniques. Major drawback of the OCR technique was due to the high sensitivity of the technique towards misalignment and different size of characters and numbers. Limitations of other methods are; PNN technique is sensitive to brightness of light and Fuzzy system fail to detect the boundaries and misidentifies number like '1' and '7'. In OCR application, to identify segmented characters different algorithms are used such as Hidden Markov Model (HMM), Hausdorff distance, SVM based character recognition and template matching. Artificial Neutral Networks technique which is a comparison method using interpolations, approximations and discussions to yield the closest digit in the data sheet to the segmented digit can also be used (Wanniarachchi, Sonnadara & Jayananda, 2007). But this method won't provide hardware and time optimization. (Babu, Siva & Parasuraman, 2010). One other available method is template matching which is a simple and a fast process. But if the characters show certain variations then it is hard to use direct template matching and also for proper identification, template matching require large templates sometimes even more than one template for each character and this will lead to an increase in processing time (Barroso, Rafael, Dagless& Bulos-Cruz, 1997). Hence instead of using direct template matching a feature based technique is being used in where several features will be extracted from each character followed by template matching (Babu, Siva & Parasuraman, 2010). Further analysis on these methods has led to identify that the critical points method proposed by Schepin and Nepomyaschin is a successful approach for this purpose as an OCR engine since it is based on topological analysis of character and is characterized by finding the critical points of the boundary (Barroso, Rafael, Dagless& Bulos-Cruz, 1997)

Another application of image processing for object identification which is the barcode recognition (Hashim, Saad, Zakaria, Ibrahim & Sakaguch, 2013). This is a widely used process and here they have developed a barcode recognition technique which has been proposed as a cost effective method since the mostly used IR sensor based decoding is expensive to handle. The other proposed method is an angle invariant method for barcode detection based on the properties of the Hough Transform (Zamberletti, Gallo & Albertini, 2013). This method is also effective in detecting twisted barcodes. They followed locating the barcode, angle detection and bounding box detection steps in their mechanism. In the earlier method they have suggested an algorithm which uses camera to capture the image and then display the barcode information instantly. In this the basic method followed is; input of the image, convert to black and white, recognize barcode type, image processing and decoding the barcode.

III. Methodology

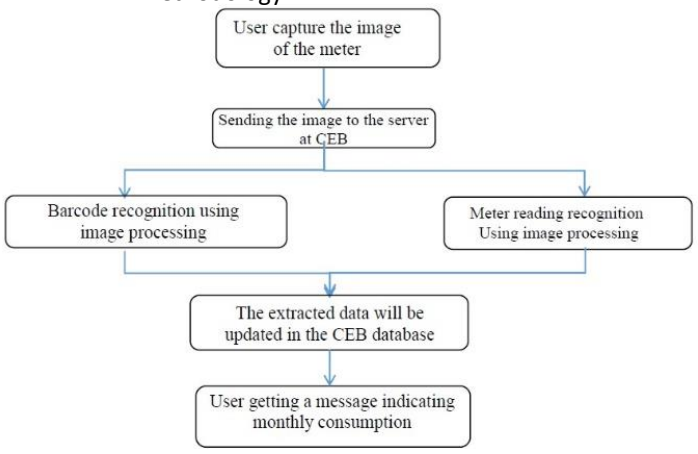

Figure 3. Process Followed

Figure 3 depicts the process followed and in that capturing the image is the user side and everything else happens in the server side. So in developing this system the total procedure is divided into four sections as;

Android App development, image transfer from phone to the server using a web service, image processing and calculation of the bill and sending feedback. Out of these 4 sections the main focus is Image processing part because it is the core of this system. In this research two image processing procedures are performed and in both cases a number associated with the image is the feature extracted. For both cases image processing algorithm is developed using the image processing toolbox of the MATLAB R2014a software. Once the image is sent through the app by the user, it is received to the folder "image receiver" in the CEB server via the web service where the further processing happens.

A. Meter reading Identification

This is the most important section in this system and the accuracy of the whole process mainly depends on this. What happens in this section is that, extracting the numbers associated with the meter reading from the image sent by the user. The algorithm followed in number detection is as illustrated in figure 4.

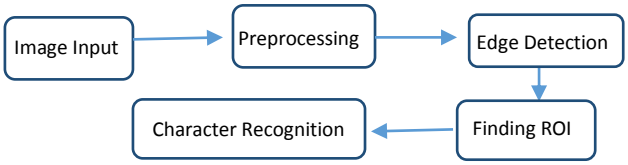

Figure 4. Image Processing Algorithm for number identification

Initially the original image received at the server sent via the web service is fed into the system. Next phase is preprocessing where the images are resized to bring all the images to a common format. This resize process will be done in pixel level. The two processes of number detection and barcode recognition happens one after the other. So the image need to be divided into two portions for further processing. Hence in the next step the image is cropped based on coordinates. Next phase in preprocessing is gray scaling the image. Rather than dealing with the RGB colour space it is always recommended to convert any image into gray scale so the concerns are limited only to a few variations of gray levels in the further processing. Any image or a signal consists of several unwanted noise in addition to the information signal. So before going into next steps of image processing that noise associated with the image should be removed. Hence, after gray scaling noise reduction of the image is done. In this the Matlab image processing toolbox provide several noise filters and some of them are: Gaussian filter, Median Filter and Wiener filter. Out of these most commonly used type of filter is the median filter and it has been used previously by most of the researches. But in this research all three filter types are tested and found that a better result is obtained by using wiener filter. Sometimes if median filter is used and proceeded it won't even recognize the characters properly because image is full of noise and not clear for identification. But in using wiener filter that issue is solved. That is wiener filter is more efficient in noise removal than median filter.

Next phase is Edge detection. Here the discontinuities in the intensity of the image are detected. In this research this phase will be done via a three step morphological process. For this to happen first a structuring element to do the morphological operations must be selected. A structuring element is a matrix made of 1s and 0s and it is of the shape determined by the user. There are several available structural element shapes in the Matlab image processing toolbox. For E.g.: disk, line, square, octagon, diamond, rectangle etc. However here disk is used as the structuring element as it seemed to generate the best result. The three phases of morphological operations are;

1. Dilating the image – Dilation basically takes the gray scaled image and the structuring element as two inputs. And it basically thickens or grows the edges of the image by adding pixels based on the structuring element used.

2. Eroding the image – this is the exact opposite of dilation and here the image will be thinned by removing pixels out of it again based on the structuring element selected.

3. In the final step the difference between the dilated and eroded images will be obtained and it gives the true edges or the boundaries of the objects within the image.

Next stage which is finding the Region of interest (ROI), is the most important segment of the whole process which basically effects the accuracy of the output. Here first the output from the morphological process will be filled back so that all the objects in the image are filled with white pixels remaining the background to be black. Here to locate the ROI bounding boxes are used which means a bounding box around each of the filled objects within the image will be drawn according to the predefined dimensions. Then an array of bounding boxes of interest will be determined. For this a histogram of the y-dimension widths of all boxes are created and from there the indices corresponding to frequency '5' are found. Here 5 is used as the frequency because, according to the information received from CEB, the bill is only calculated by considering the first 5 numbers that is, the decimal value is excluded from the reading. Hence to make the system easier the algorithm is designed such that it will only consider the bounding boxes around the 1st five objects in the image.

The final step of the number detection process is character recognition. There are several methods of accomplishing this task as highlighted in the previous research works. Yet 3 most widely used methods are, Template matching, artificial neutral networks and

Support vector machinesOut of the three methods, template matching is the process of matching the characters identified in the previous step with the pre-determined template and finding the most similar candidate to the template. This is a very simple and a fast process but if the characters contain various fonts then the template size used need to be increased since there should be a template for each character in each font and this would slow down the processing speed of the system. Because as the used no. of templates increase it takes more time to compare the characters with the templates. However in this research it is only necessary to identify a set of numbers from 0-9 each with a similar font.

Due to that reason template matching technique is used here. A set of templates each of the size 24*42 pixels are created and saved as a monochrome bitmap image so that it would consume a less memory space .And then out of the available templates a matrix of templates are generated and saved as a MAT file. So once after the ROI is identified from the previous step, each and every character will be matched with the saved matrix of templates and the output is displayed in a text file. Figures 5 to 12 depicts the results obtained in each of the aforementioned phases.

B. *Barcode recognition*

This is the second branch of image processing associated with this research. However, barcode recognition is not a new application and hence instead of developing a new program an existing barcode recognition algorithm is used. This section is also developed using MATLAB R2014a.

Figure 5. Input of the Image

Figure 6. Grayscaling

Figure 7. Dialating

Figure 8. Eroding

Figure 9. Result after morphological operations

Figure 10. Final Result after identifying the region of interest

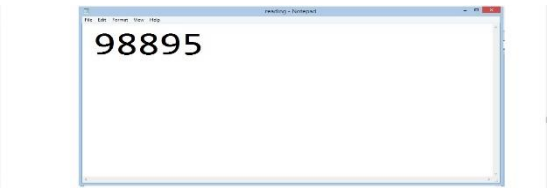

Figure 11. Output

IV. Results

A. *Accuracy of recognition of individual digits*

The system is tested for real images of electric meters obtained from camera phones. First the results of individual digit recognition are analyzed. For this purpose a set of 30 samples from each digit is used. Such obtained results are illustrated in figure 12.

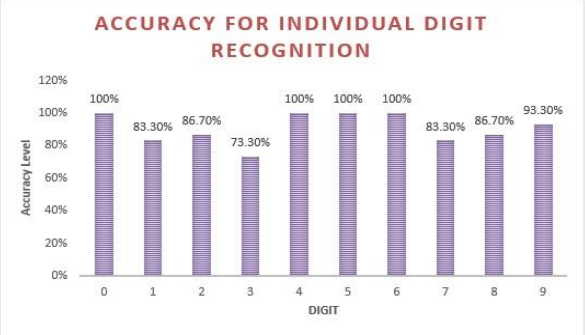

Figure 12. Results for accuracy of individual digit recognition

Here the accuracy level of recognizing number “1” is low because the template of both 0 and 1 happen to be similar hence causing falsely recognizing “1” and “0”. Similarly in most cases recognition of “2” and “7” are low because the similar shapes in their templates leads to a misidentification of the numbers. Furthermore after the filling operation number “8” appear to be similar to number “0”. Hence the accuracy level of recognizing “8” is also comparatively low. In addition due to the odd shape of the number “3” it is not recognized properly affecting it to have the least accuracy of recognition of 73.3%

B. *Accuracy of the system for different camera resolutions*

Next this system is tested for different resolutions of image capturing through various mobile phones starting from 2.4 MP up to 16 MP. For each resolution a test set of 10 samples each is used. These results are depicted in figure 13.

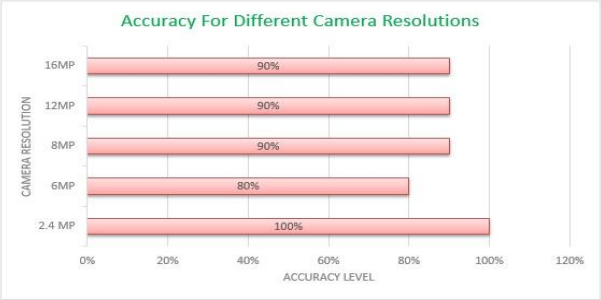

Figure 13. Accuracy for different camera resolution

When the resolution of the image is increased the amount of details captured in the image also increase. This cause the image processing system to read the unwanted objects as well. So in the final stages of the system even these unwanted objects are indicated as parts of numbers. This leads to reduce the accuracy of image recognition process and hence as the resolution increase a reduction in the accuracy of the system is observed.

C. Overall Accuracy for number recognition

For the purpose of checking the overall accuracy, a set of 110 samples obtained from different electric meters is deployed. This system yield an overall accuracy of 90% in this by correctly identifying 99 images out of the used set.

V. Conclusion

This research is focused on giving a solution to a major problem in CEB billing process which is known as assess or estimation billing which has been an issue for more than 250 000 of CEB customers. However in order to successfully utilize the proposed method the intervention of the customer is also required. Because with this system the responsibility of sending the data to CEB database is handed over to customer. But since we developed this system including a barcode system to identify the customer the issue regarding the authenticity of the information sent will be solved. Furthermore this method is proposed along with time to time visits by CEB officials to customer premises to prevent misuse of this technique. The main advantage in this process is that no additional cost or equipment is needed. Nevertheless the overall accuracy of the system is limited by the following constraints; Reflections caused by bad lighting conditions appear as filled objects in the final image output and tilting of the overall image. So the cropping function would eliminate valuable information in the image. However even with all these constraints we were able to develop this system to correctly identify the CEB meter reading value with an overall accuracy of 90%. Hence this system can be considered as a suitable method to implement.

VI. Future work

Up to now, the image processing algorithm is developed only for the Ante Leco meter type which is the most common type of meter used for household with a percentage of 40%. In future this algorithm can be improved and implemented on other meter types also. Another area which can be improved is security. For this GPS can be implemented in order get the customer's location. This way, illegally obtaining images from other's meters can be prevented. Moreover, the accuracy this system can be extended up to a level that there's an option for the customer to type and send the current meter reading along with the image. So that in comparison if there's any mismatch between the sent value and the value obtained through image processing then CEB officials could take actions accordingly.

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