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## Article

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## Research paper

## Text detection and recognition in raw image dataset of seven segment digital energy meter display

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## ABSTRACT

The article describes the collection of the dataset of raw images of digital energy meters display, text detection and recognition of seven segment numerals from collected samples that may be helpful in reducing the cost of advanced metering infrastructure (AMI). The presented dataset has tremendous potentials in fully automated optical character recognition (OCR) based electricity billing. The dataset has been named as 'YUVA EB Dataset' that has the collection of digital energy meter images. The images have been captured under day and night light conditions. The research work on recognizing the text from seven segment display in energy meters has been carried out using our dataset under the challenging text recognition conditions like tilted position, blurred, day and night light captured images. MSER and labeling method based OCR algorithm has been used for text detection and recognition.

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## 1. Introduction

The advent of technology has charted an amazing and noble growth curve for the past two centuries. The advancement comes to a great distance from punch cards in the 1950s to the graphical interface in the past decade to human-based interactions in the present and the future. The usage of mouse and the keyboard is comfortable for last few years to assist as interfaces between human and the computer.

However, the ability to use human-based computer interaction would make things easier mechanically for the users, but would be difficult to succeed for the researchers. The pioneering achievements due to continuous research in man-machine communication may bring the scenario like interactions between human.

Various techniques using magnetic stripe, speech recognition, identification using radio frequency, bar code, and Optical Mark Recognition (OMR), and OCR fulfill the automation needs in various applications (Weigelt et al., 2010).

OCR process converts scanned images of typewritten, handwritten text into machine-readable text. It is a method of digitizing the printed texts that electronically storable, searchable and used in machine processes such as text to speech, machine translation, and text mining. OCR technology has been applied to

revolutionize the document management process. OCR enabled the scanned image files turning into the fully searchable document with text content that is recognized by the computers. The OCR helps the people to extract the related information and records it automatically, and the result is accurate and processes the adequate information in less time. The recognition accuracy of OCR method differs with the approach. The scene text recognition has the lot of applications such as navigation, road sign detection, language translation, etc. Shi et al. (2014). The quick response code or barcode techniques offer only the limited information. Text based tags may offer full information instead of barcode technique. The scene text recognition is a challenging task due to cluttered noise backgrounds and non-text outliers. It also faces difficulty due to distinct text patterns like the difference in character type, font type and size of the font (Yi and Tian, 2014).

Smartphones are the preferred platform for developing the novel applications in several fields like computer vision. The usage of smartphones continues to increase in the near future. They become more powerful with improved capability of computing and imaging. It is easier to embed the task in mobile using applications than desktop computers (Chouiten and Schaeffer, 2014). The proposed approach brings the idea to utilize Smartphones for automation in electricity, gas or water billing. A dataset is a collection of statistical data or samples of images that are useful to train the network or to test the various algorithms or tasks. The article describes data collection and method of text detection and recognition from samples. The collected samples

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are real-time images that have been captured from the consumer premises under different lighting, blurred and tilted conditions. The OCR based energy consumption billing using Smartphone for digital electricity/energy meters may be employed effectively using our raw dataset. Accurate and efficient text detection and recognition in camera captured images is still an open issue in this field. Image analysis that involves the study of segmentation, feature extraction, and classification techniques or text detection and recognition in camera captured images can be carried out under the various constraints using our raw dataset. The raw dataset helps to implement the image processing based Automatic Meter Reading (AMR) and to recognize the characters from the digital energy meter display image that contains the seven-segment numerals. The objective of the article is to create raw image dataset and creating The Common Objects in Context (COCO) annotation JSON file using 'Labelbox' tool, to help the energy/water/gas consumption billing completely free from the task of the meter readers by implementing OCR to extract the value from digital meters and to implement maximally stable extremal regions (MSER) based preprocessing to overcome the challenges in text detection and text recognition in camera captured images. The article has been organized as review of existing work, dataset collection, text detection and recognition, results followed by conclusion. Section 2 discusses with various existing dataset of text images as well as image dataset of meter readers. Section 3 discusses about 'YUVA EB Dataset' collection, text detection and recognition followed by results and discussion. Section 4 discusses about conclusion of the work.

## 2. Review of existing work

### 2.1. Dataset review

Wang et al. (2014) described the topic language model GLM, TLM, rTLM adaption for recognition of homologous offline handwritten Chinese text image. Sahare and Dhok (2018) have developed the multilingual character segmentation and recognition schemes for Indian document images. They presented the robust algorithms for character segmentation and recognition that supports the multilingual Indian document images with intermixed texts of Devanagari and Latin scripts. They tested their segmentation process with *Tobacco-800*, *Proprietary database – Latin Script* and *Proprietary database – Devanagari script* dataset. Also the Comparative analysis of recognition algorithm on different databases *CVSLD*, *CPAR* and *Chars74k Latin script* has been done by them. Rashid et al. (2013), Morillot et al. (2013), and Al-Hajj Mohamad et al. (2009) used APTI, NIST and IFN/ENIT Arabic language dataset for test the developed algorithms. AMR interconnects with OCR in applications like license plate/number plate recognition (Zhang et al., 2007). The various other dataset is available for various languages and numerals. Ujjwal et al. (2017) describes a system to generate a database of synthetic samples from a small set of original online handwriting specimens. The developed database by them has large number of online handwritten word samples that is used to train and assess the performance of the existing three online handwriting recognition systems. The 'chars74k dataset link' (The chars74k dataset [The chars74k dataset, 0000](#)) is available in reference that has symbols used in both English and Kannada language. In the English language, Latin script (excluding accents) and Hindu-Arabic numerals are used and referred as "English" characters set. It consists of 64 classes includes numerals 0–9 and alphabets A–Z, a–z. Totally 7705 characters obtained from natural images, 3410 hand drawn characters using a tablet PC, and has 62,992 synthesized characters from computer fonts.

Yang et al. (2019) has constructed and released a dataset that contains 6000 water meter images with labels. Laroca et al.

(2019) have developed UFPR-AMR dataset, contains 2000 images taken from inside a warehouse of the Energy Company of Paraná (Copel). Both of the dataset covers the images of analog meters. Even though the numerals present in large scale in these datasets fail to help the researches to perform seven segment numeral text recognition because of the unique appearance of seven segment digits compared to other numerals. The seven segment numerals present in the energy meter display has isolated segments. It requires some preprocessing steps like dilation to become identical English numerals.

In General, researchers have the interest in the implementation of OCR because of the demand by real world applications. The few applications are assisting blind persons to walk freely on the street, helping a driver to drive a vehicle safely, and helping tourists to reach their destination without help and with GPS information and retrieving games from the sports databases.

In these applications, recognition, and understanding the text in the images play a vital role. In the meantime, due to scene text or camera captured images like digital energy meter display image that can vary largely in fonts, font size, backgrounds, contrast, orientation and other distortions, the problem of text in scene image or camera captured images has become complex and challenging.

Many factors influence the precision of text recognized through OCR. These factors include scan resolution, scanner quality, printed documents type either photocopied or laser printer, paper quality, linguistic complexities, fonts used in the text and dictionary used. The non-uniform illumination and watermarks are examples of problems that influence the accuracy of OCR compared to a clean text on a white background. The preprocessing stage is necessary to obtain better text recognition rate, therefore; using effective algorithms of preprocessing makes the OCR system more robust.

The text detection from camera captured images realized that there are still many challenges to achieve good accuracy for both text detection and text recognition. Accurate and efficient text detection in natural scene images is still an open issue in this field due to unpredictable characteristics of scene text. Segmentation of words and characters from detected text line to improve the recognition rate is another research issue here. This is because of low resolution, complex background, low contrast and small fonts that hard to find features which segment words and characters from the text line correctly. Achieving good recognition rate for scene text is still an elusive goal due to lack of robust and powerful binarization method that separates foreground (text) and background (non-text) properly. State-of-the-art OCR systems can provide best results for high resolution and high-quality document images with a clear background. In practice, many real-life documents rarely satisfy these optimal conditions. The presence of arbitrary layouts, complex backgrounds, noisy data, merged or broken characters, size and color and variation in font styles can drastically affect the performance of any OCR system. Also, camera-based images, due to the less-constrained mode of acquisition, are often characterized by non-uniform illumination, focus misalignment, poor resolution, perspective distortion and 3-D deformation.

Wahyono and Jo (2015) propose a method for text detection in LED display and recognition in images of the natural scene. The recognition process is consisting of two steps. The first step is to apply canny edge detector to detect the character pixels which appears in the LED display area. The character feature extraction has been performed based on the spatial information like centroid and orientation of the character candidate. These values analyzed using a k-nearest neighbor algorithm for alphanumeric character classification. The recognized characters combined into a text line based on the similarity of their characteristics like aspect

ratio, width, height, and color. The post-processing is then applied for rectifying the falsely recognized characters. In experiments, the proposed method achieves 68.8% and 47% for text location detection and recognition rate, respectively. These results show the effectiveness of the proposed method by them for detecting and recognizing the LED text in natural scene images.

Rodriguez et al. (2014) discussed the necessity to develop tools that allow the consumers to know about their electricity consumption. The proposed Hausdorff distance for meter reading (HD MR) by them achieved a 99.9% recognition rate for analog type of meters, even when recognized numbers are under rotation in the energy meter. The recognition time is maximum of 31 msec; hence, the proposed method proves to be efficient and capable in real time for the task proposed. Retrieving texts in both outdoor and indoor environments provides contextual clues for a broad range of vision tasks. The image retrieval algorithms performance depends critically on the performance of the modules of text detection. For example, two book covers of identical design but with different text, prove to be virtually indistinguishable without detecting and OCRing the text.

A survey work of existing systems for detection, localization, and extraction of texts embedded in images of natural scenes can be found by Liang et al. (2005). The two general categories of available methods are texture-based algorithms, and Connected Component (CC) based.

The first category of methods segments the image into a CCs set, and then the classification carried out on each CC as either non-text or text. CC-based algorithms are comparatively simple, but usually, the algorithms lose to be robust. The texture-based methods assume that text in images has different textural properties compared to non-text regions or the background. The second category algorithms have high computational complexities. Additionally, a few authors studied various combinations of the above two categories of methods.

Unlike scanners, the digital or mobile cameras have far less control of the lighting conditions of the acquisition environment. Uneven illumination is common, due to both the natural environment such as reflective surfaces or shadows and lack of controlled lighting.

## 2.2. Implementation and challenges in smart metering

Smart or advanced metering is a different means of estimating and managing energy and water use. It involves two essential elements; a meter that can capture usage information over short time intervals, typically 30 min or less; and a communication system, preferably two-way that can transmit the usage information to the service troll instructions (Tsukamoto et al., 2015). Smart meters offer the wide range of functions and capabilities for service providers and consumers that are not available with conventional meters. They can even promote consumers to begin the task of service providers by becoming electricity generators by making it easier to serve and sell solar and other renewable electricity into the utility grid.

Various transmission options are possible, such as over the telephone lines via a modem, electric power distribution lines or using the mobile phone or other wireless technology. Bahmanyar et al. (2016) described the challenges in the implementation of smart metering. The first challenge in the deployment of Advanced Metering Infrastructure (AMI) is from the economic perspective. The design, installation, and maintenance of the AMI involve many issues and require several billion dollars of investment for deployment and maintenance.

Table 1 presents the average Smart Grid cost per customer (Bahmanyar et al., 2016), based on budget information from U.S. utilities' applications for the U.S. Energy's Department, Smart Grid

**Table 1**  
Average cost per customer by smart grid component.

Smart grid component	Sample size	Average cost per customer
Smart meter	24 projects	\$291.54
Distribution automation	12 projects	\$63.64

Investment Grant (SGIG) program funds. At first glance, justifying such investment seems difficult. However, it is worth mentioning that grid modernization creates direct and indirect economic benefits for customers. So, a cost-benefit analysis would be the reasonable preliminary point for the evolution of future measurement infrastructures.

The benefits can be differentiated to direct and indirect ones. Direct benefits are those that could directly affect customers' bills, while the indirect benefits are regarding reliability and environmental performance improvements, which will have future economic impacts. In the path of the smart grid, besides the economic challenges, several security and privacy concerns arise. By deployment of smart meters with two-way communication capabilities, customers work closely with the utility to manage energy usage. The methods like proposed by Johari et al. in capturing images may reduce the infrastructure cost. In their system, the captured images will be sent through using mobile phone via GPRS/GSM to the GSM modem. The image will be received and read by GSM modem and saved to the database in central computer. In the similar way, the received image can be processed using our proposed algorithm to detect and recognize the text.

## 3. Dataset collection & text detection and recognition

### 3.1. Dataset of seven segment digital energy meter display

The raw dataset presented in this article contains images of energy meter display that contains seven segment numerals. The total number of samples collected is 169. The Tamil Nadu Electricity Board (TNEB) mostly uses a Genus, L&T, HPL, Avon, Maxwell, and Capital make digital energy meters. The digital energy meters are consisting of seven segment type numerals. All the meter samples have the decimal points before the last digit. The image should be captured in a way that there is no flash or reflection from the display. Table 2 shows the classification of energy meter display image samples that are categorized under different conditions. The raw dataset has 50-day light and tilted, 49-night light and 20 blurred images. Dataset specifications and its properties has been given in Tables 3 & 4 respectively. Fig. 1 shows the distribution of digits in each digit position. It is found that except digit 0 all other digits are almost uniformly distributed and same can be observed from Table 5. Totally 985 digits has been captured. Fig. 2 shows the classification of image samples based on the number of digits in each display. The energy meter display has its value depend on the usage of electricity. The four- and eight-digit display samples are less in count because of the less usage by consumers.

Figs. 3, 4, 5 & 6 show the images of the collected samples. The 'YUVA EB Dataset' can be accessed using the link provided in the Specifications Table 3 as well as from 'Mendeley' database.

The images captured in a way that there is no flash or reflection from the display. The automation in Gas and water consumption can also be implemented using the dataset. The labeled images have been shown in Fig. 7. The labeling process has been done using the 'Labelbox' tool. The objects have been classified as text 0 to 9. The COCO annotation JSON file is available with the accessibility link provided in Table 3.

### Distribution of Digits in Each Position

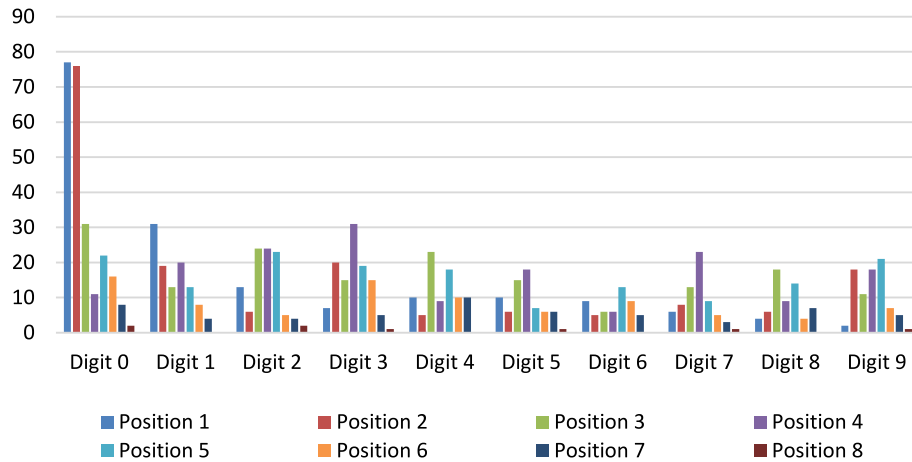


Fig. 1. Distribution of digits in display.

### Image Samples

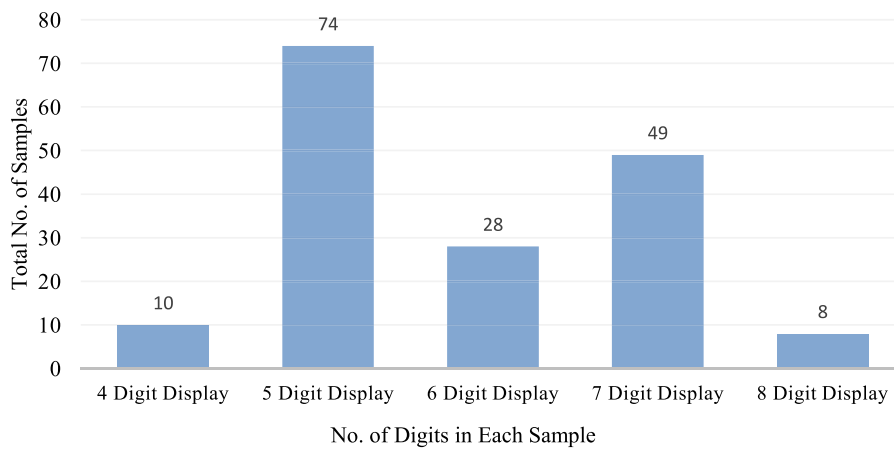


Fig. 2. Image samples classification based on number of digits in the display.

Table 2 Collected samples.

Company make	Conditions			
	Day time	Night time	Tilted	Blurred
Genus	22	23	25	8
L&T	15	6	4	6
HPL	11	13	12	2
Avon	2	5	4	3
Vision tek	-	-	3	-
Maxwell	-	2	-	-
Capital	-	-	2	1
<b>Total</b>	<b>50</b>	<b>49</b>	<b>50</b>	<b>20</b>

Table 3 Dataset specifications.

Specifications	Description
Subject area	Digital image processing
More specific subject area	Optical character recognition – Text detection and recognition
Type of data	Images of digital energy meters consisting seven-segment numerals
Image acquisition conditions	The night, daytime, tilted images have been captured using high-resolution digital camera and blurred images captured in low pixel mode
Sample collected location	Tamil Nadu, India
Accessibility link	The 'YUVA EB Dataset' can be accessed using the following link (Copy and Paste the following link in your browser): <a href="https://drive.google.com/drive/folders/1J9TYUiLKdJKfSeotL-_ElyvXQ-3pE282?usp=sharing">https://drive.google.com/drive/folders/1J9TYUiLKdJKfSeotL-_ElyvXQ-3pE282?usp=sharing</a>

### 3.2. Text detection and recognition in raw image dataset

Perspective distortion occurs when the text plane is not parallel to the imaging plane. It usually occurs while capturing text on buildings, billboards, meter display, road signs, or charts where it is infeasible to have an orthographic view. The effect is that characters situated far away appear smaller and the parallel line assumption no longer holds in the image. In this article, the images have been captured in parallel with energy meter display with approximately one feet distance from display. In this article, the seven-segment numerals have been detected and recognized in the energy meter display image. The problems addressed are

uneven illumination, complex backgrounds, noisy data, merged or broken characters. The MSER algorithm and image dilation algorithm is applied to conquer these problems. The collected samples can be applied with MSER text detection algorithm (Yin et al.,

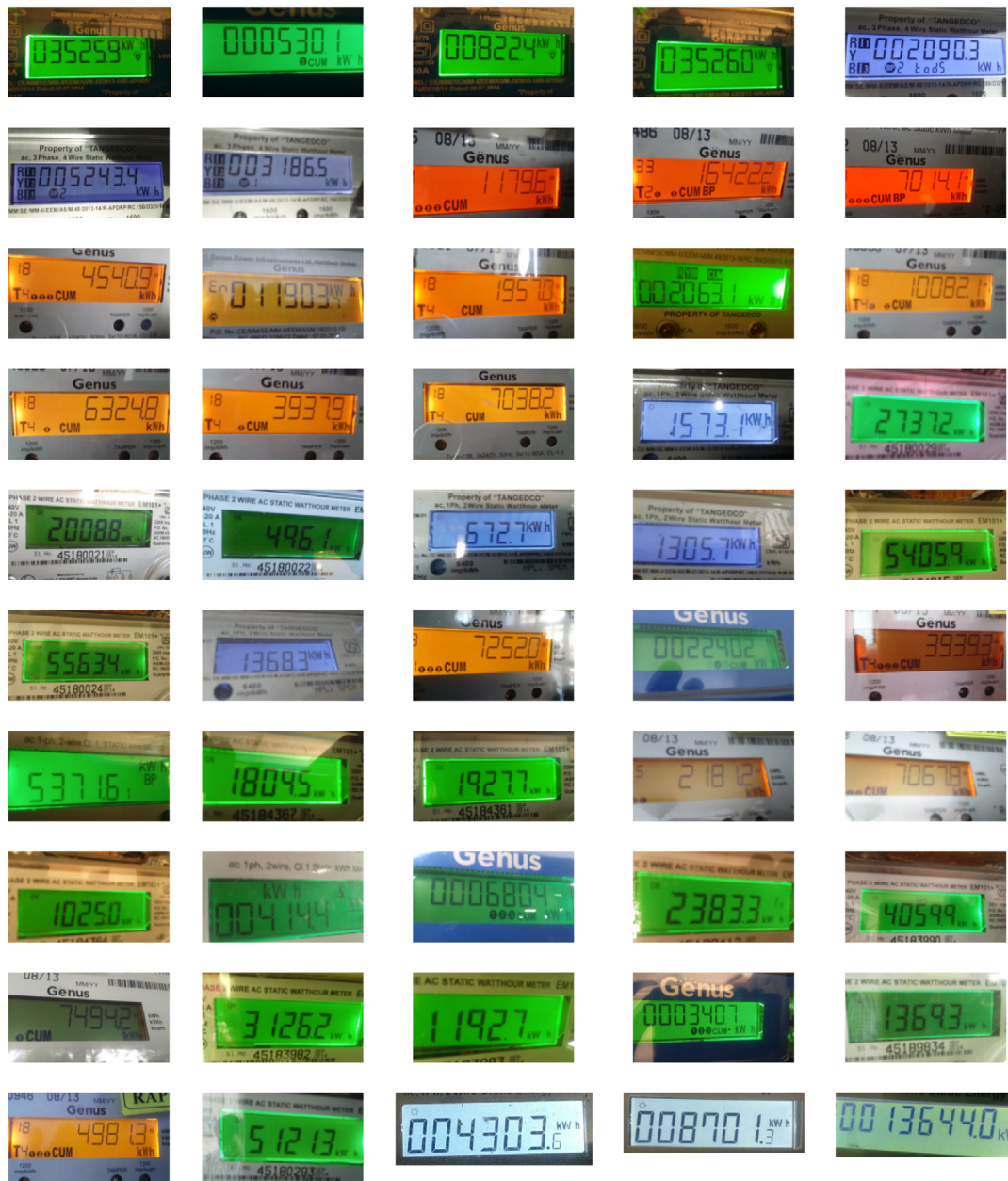


Fig. 3. Images captured during daylight.

Table 4  
Dataset characteristics.

Properties	Description
Camera model	Sony D2212
Focal length	3 mm
Metering mode	Center weighted average
Color representation	sRGB
Resolution	72 dpi
Bit depth	24

Table 5  
Distribution of digits.

Digit position	1st	2nd	3rd	4th	5th	6th	7th	8th
Digit 0	77	76	31	11	22	16	8	2
Digit 1	31	19	13	20	13	8	4	0
Digit 2	13	6	24	24	23	5	4	2
Digit 3	7	20	15	31	19	15	5	1
Digit 4	10	5	23	9	18	10	10	0
Digit 5	10	6	15	18	7	6	6	1
Digit 6	9	5	6	6	13	9	5	0
Digit 7	6	8	13	23	9	5	3	1
Digit 8	4	6	18	9	14	4	7	0
Digit 9	2	18	11	18	21	7	5	1
Total	169	169	169	169	159	85	57	8

Total No. of digits = 985

2014) followed by binary mask and image dilation algorithm. To eliminate the negative regions i.e., text regions candidates can be filtered out using the powerful hybrid filter with CCs-based filters with good efficiency (Yang et al., 2017). The successful samples

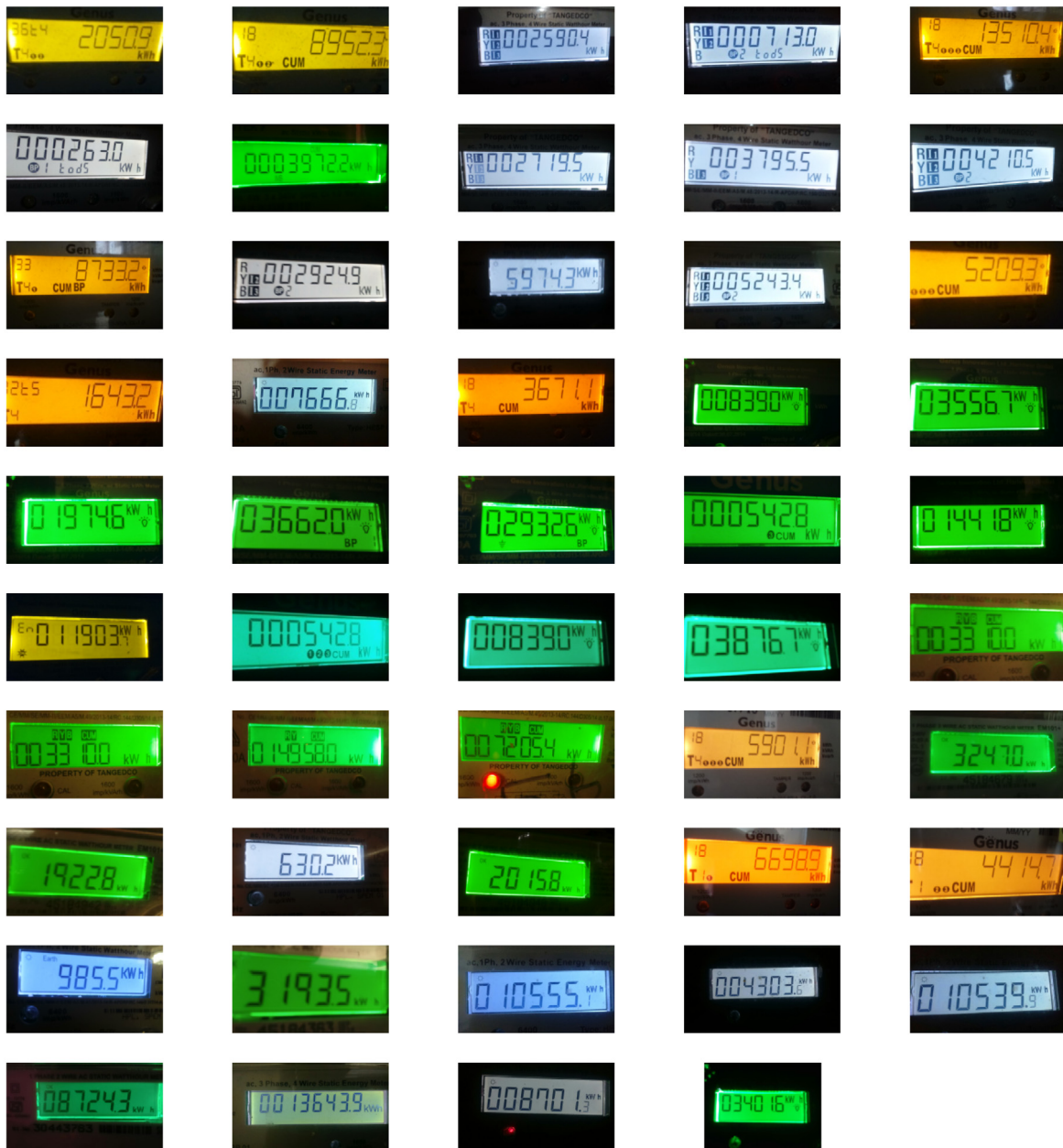


Fig. 4. Images captured during nighttime.

can be processed through OCR algorithm to obtain recognized output.

#### MSER feature detection algorithm

MSER algorithm is used to detect the text regions in an image. MSER detection is a common task performed on unstructured scenes. The regions are defined solely by an extremal feature of the intensity function in the region and on its outer boundary. The MSER is represented by the position of a local intensity minimum (or maximum) moreover, a threshold.

The MSER detection takes only 0.14 s for a  $530 \times 350$  image on a Linux PC with the Athlon XP 1600+ processor (Matas et al., 2002). MSER detection works well for text because the consistent color and high contrast of text lead to stable intensity profiles. The 'detectMSERFeatures' function available with MATLAB software is used to find all the text regions within the image. Over an extensive range of thresholds, the local binarization is stable in certain regions. The input to the MSER algorithm is a grayscale

image  $I$ . The output of the MSER algorithm is a sequence of images  $(I_t)_{t=0}^{255}$  which is formulated as follows.

An input image 'I' is successively binarizing the grayscale image with a threshold 't' iterating from 0 to 255. The first sequence in the image 'I<sub>0</sub>' is completely black. In the next sequence of the image white areas appear and grow. And the latest sequence I<sub>255</sub> is entirely white. There are also implementations of this algorithm when a sequence is formed conversely. Therefore, the first image in the sequence is white and the newest image is completely black. The white areas in the sequence are called extremal regions. For each extremal region, it can be found for how many successive images in the sequence this region stays the same. Thus, by selecting a threshold value 'R', the regions can be selected that are exactly the same in at least R successive images of the sequence. Such regions are called MSER. The MSER algorithm advantage is that it is well applicable for finding text character candidates. The MSER algorithm is invariant to affine transform that can be applied to images with low quality. The

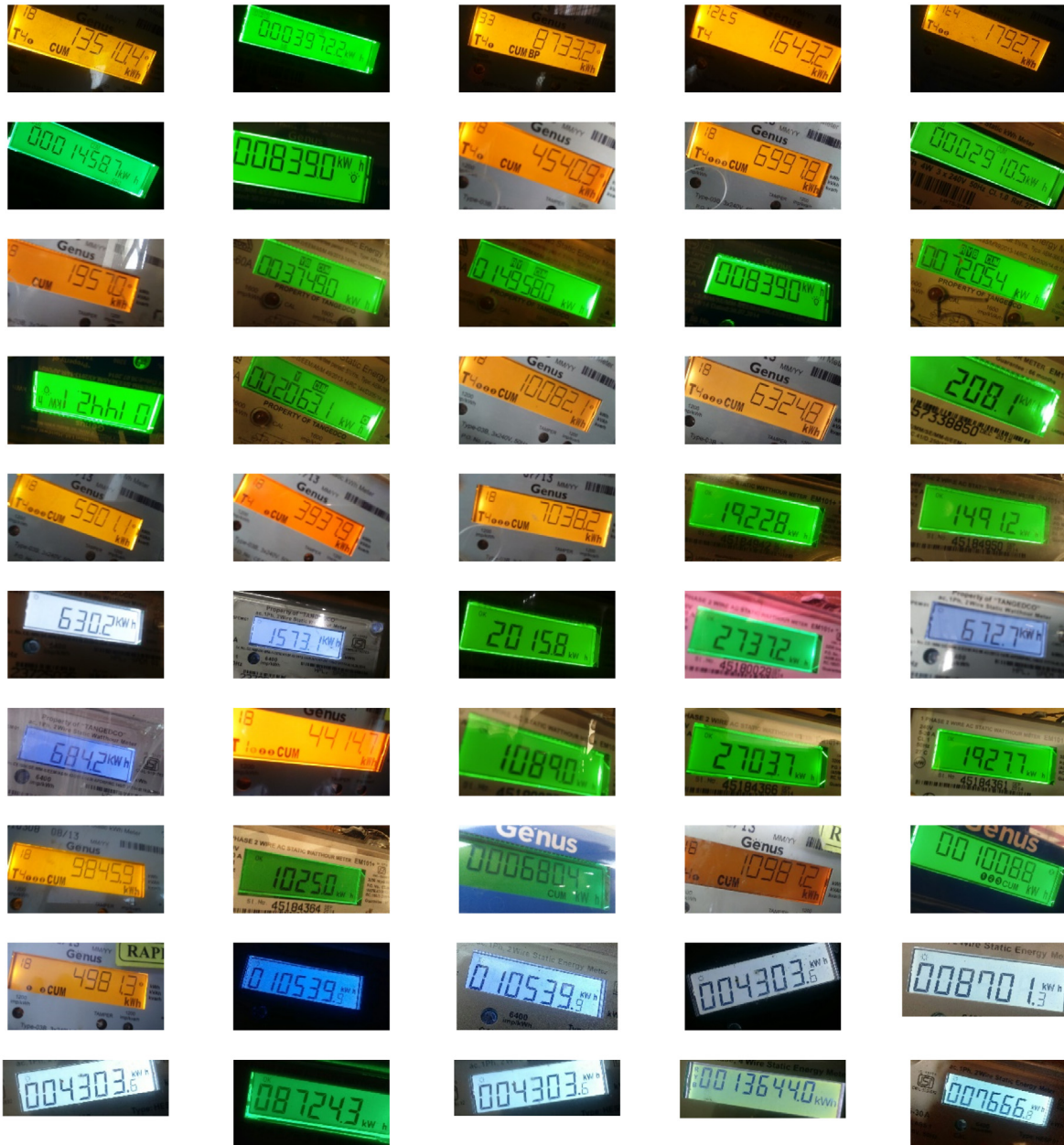


Fig. 5. Images captured in the tilted position.

region area range is selected as 200–8000 and threshold value is 0.7 for text detection.

#### Binary mask & image dilation

The MSER binary mask obtained from the MSER pixel list. Dilation is an operation that ‘thickens’ or ‘grows’ objects in a binary image. A shape controls the specific manner and extent of this thickening referred to as structuring element. Mathematically, the dilation defined in terms of set operations. The dilatation of A by B denoted  $A \oplus B$ , is defined as

$$A \oplus B = \{z | (\hat{B})_z \cap A \neq \emptyset\} \quad (1)$$

where  $\emptyset$  is the empty set and B is the structuring element. In words, the dilation of A by B is the set consisting of all the structuring element origin location where the translated and reflected B overlaps at least some portion of A (Gonzalez et al., 2009). Creation of ‘line’ structuring element using ‘strel’ object creates a flat and linear structuring element. In the  $Se = strel$  (‘line’, LEN,

DEG) syntax, where ‘LEN’ specifies the length, and ‘DEG’ defines the angle in degrees of the line measured in an anticlockwise direction from the horizontal axis.

#### OCR training algorithm

The OCR function available with MATLAB should be trained to increase the recognition rate. The following steps show the training algorithm.

Step 1: The OCR trainer Apps tab that is available with MATLAB 2016b has been opened.

Step 2: The new Session has been created to start the OCR training session.

Step 3: The new language file and its location have been created.

Step 4: The labeling method has been used and pre-label under the English language with the specific character set of ‘0123456789’ has been selected.

Step 5: The required training samples has been added.

Step 5: ROI has been drawn to do manual segmentation.





Fig. 6. Images captured using the low-resolution camera.

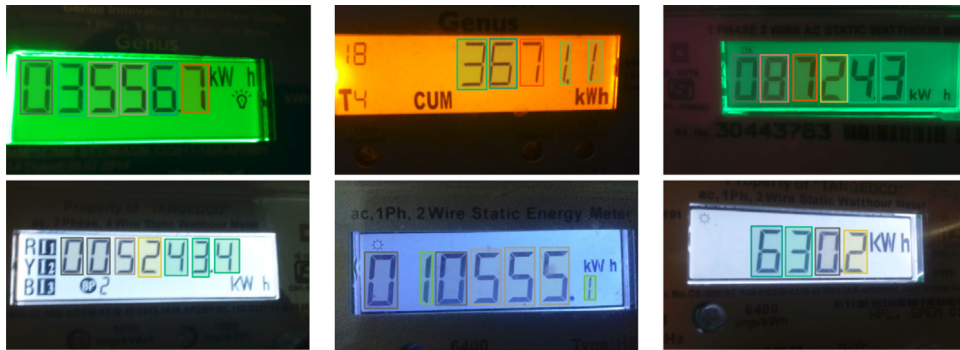


Fig. 7. Labeled images.

Step 6: The identified samples have been verified with character label. The unknown and erroneously moved samples have been transferred to the known category.

Step 7: The four to five samples have been used to train each character in the character set.

Step 8: The trained OCR language data file has been created.

### 3.3. Results and discussion

The detection of MSER regions in the grayscale has been performed with region area range as 200, 8000 and threshold delta value as 0.7. Fig. 8 shows the OCR training session settings. The pre-label using OCR tab under the Labeling method has been selected. The seven-segment display only contains the English numerals from 0 to 9. So, the 'English' language option selected and the character set defined with '0123456789'. The character set trained (training set) with four to five image samples from our dataset to train each character. The training and testing process has been done with rest of the samples.

Fig. 9 shows the manual segmentation process. The manual or automatic segmentation process is possible with OCR trainer. The automatic segmentation is not suitable due to the presence of unwanted text present in the background of the display. The manual segmentation is followed to assign the samples with defined character set. Fig. 10(a) shows the input image. It consists of kWh information and other non-required text information. Fig. 10(b) shows the preprocessing stage that uses MSER algorithm to detect text area in the energy meter display. Fig. 10(c) & (d) shows the dilated and recognized output after applying

Table 6  
Performance of proposed approach.

Digit	Training set			Test set		
	Total no. of digits	Recognized digits	Accuracy (%)	Total no. of digits	Recognized digits	Accuracy (%)
Digit 0	114	104	91.23	127	114	89.76
Digit 1	53	51	96.23	53	50	94.34
Digit 2	40	39	97.50	59	58	98.31
Digit 3	56	54	96.43	55	49	89.09
Digit 4	41	40	97.56	42	41	97.62
Digit 5	29	28	96.55	38	35	92.11
Digit 6	30	29	96.67	21	20	95.24
Digit 7	37	36	97.30	29	26	89.66
Digit 8	33	32	96.97	27	26	96.30
Digit 9	34	33	97.06	47	45	95.74
Total	467	446	95.50	498	464	93.17

trained 'ocr' function. It is observed that recognized output does not contain the decimal point.

Table 6 shows the accuracy % on each digit from 0 to 9 present in the energy meter samples. The training set and test set recognition rates are 95.5% and 93.17% respectively. Table 7 shows the comparison of recognition rate of three proposed strategies with other methods. The character recognition system proposed by Kulkarni and Kute (2016); Ghugardare et al. (2009) achieves recognition rate as 79% and 92.72% respectively. The method proposed by Kulkarni and Kute (2016) uses energy meter display and Ghugardare et al. (2009) uses measurement instruments display with very less number of samples.

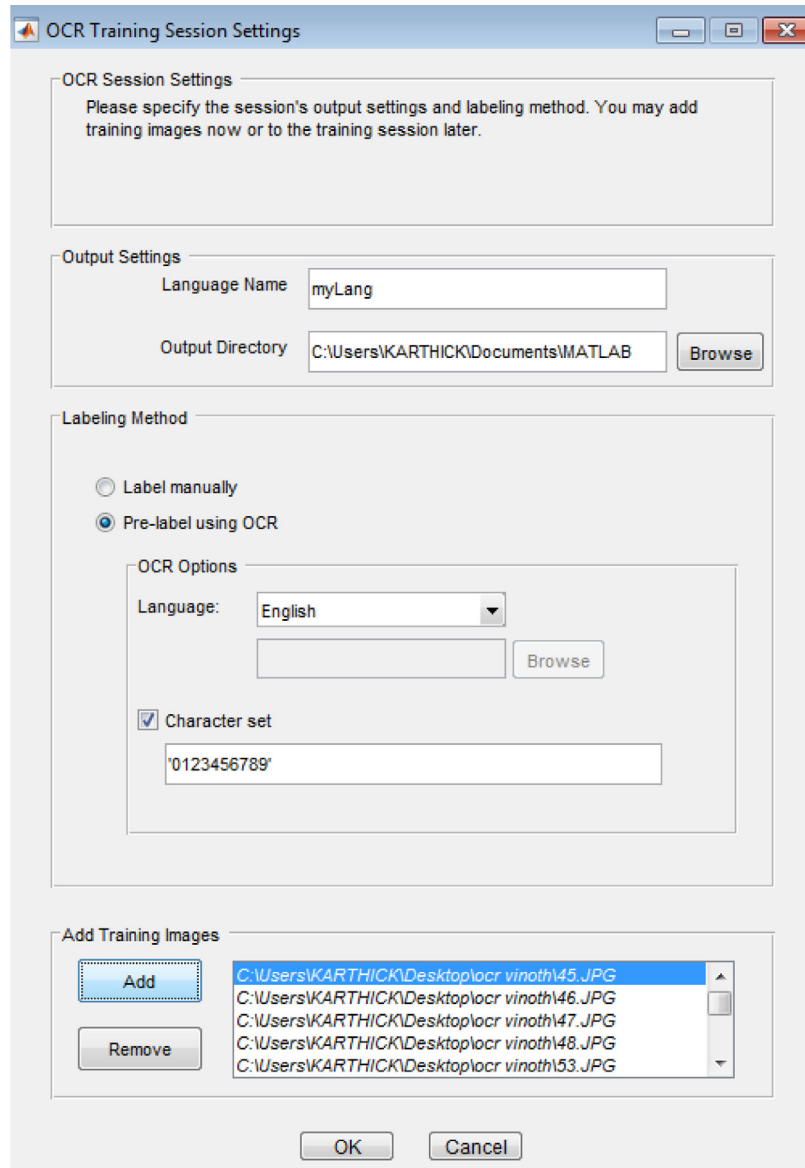


Fig. 8. OCR training session settings.

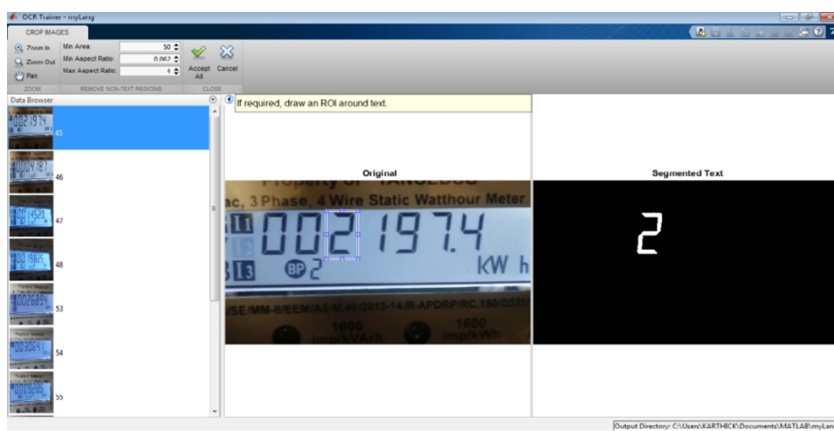
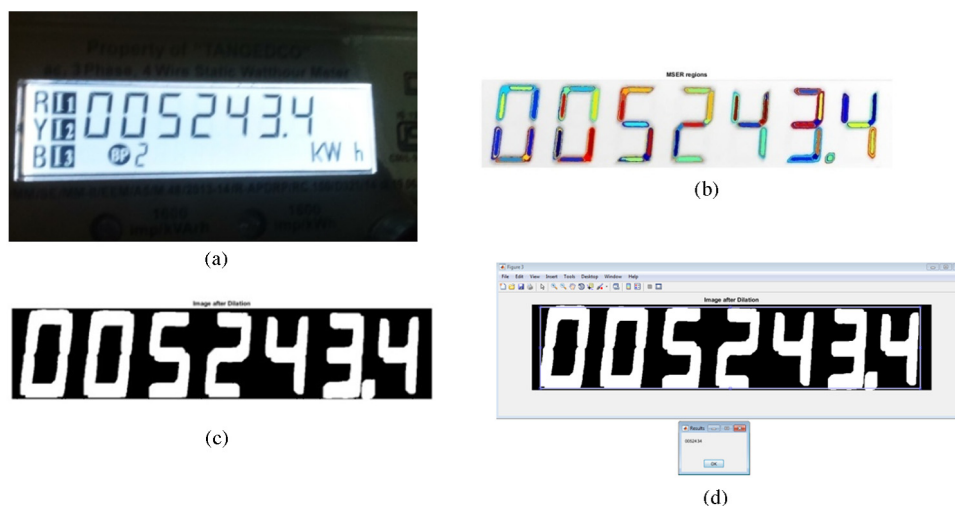


Fig. 9. Manual segmentation to train each character.



**Fig. 10.** (a) Energy meter image (b) Detected MSER regions from grayscale image (c) Dilated image (d) Recognized output in the message box.

**Table 7**  
Comparison with existing methods.

S. No.	Methodology	Type of device	Recognition rate (%)
1.	Kulkarni and Kute (2016)	Energy meter display	79
2.	Ghugardare et al. (2009)	Measuring instruments	92.72
3.	Proposed method (Test set)	Energy meter display	93.17

#### 4. Conclusion

The existing open source OCR software could not recognize the text of seven-segment numerals because of the discontinuity in the digit representation. Implementation of OCR may help to bring automation in energy management process. The automation in Gas and water consumption can also be implemented using our dataset. The research work also addresses the reduction in infrastructure cost issue in smart metering method in measurement and management of electricity usage. The proposed method of text detection and recognition algorithm attains better accuracy compared to existing methods.

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