Lecture Notes in Networks and Systems 43

P. Nagabhushan
D. S. Guru
B. H. Shekar
Y. H. Sharath Kumar *Editors*

Data Analytics and Learning

Proceedings of DAL 2018

Springer

Lecture Notes in Networks and Systems

Volume 43

Series editor

Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

The series "Lecture Notes in Networks and Systems" publishes the latest developments in Networks and Systems—quickly, informally and with high quality. Original research reported in proceedings and post-proceedings represents the core of LNNS.

Volumes published in LNNS embrace all aspects and subfields of, as well as new challenges in, Networks and Systems.

The series contains proceedings and edited volumes in systems and networks, spanning the areas of Cyber-Physical Systems, Autonomous Systems, Sensor Networks, Control Systems, Energy Systems, Automotive Systems, Biological Systems, Vehicular Networking and Connected Vehicles, Aerospace Systems, Automation, Manufacturing, Smart Grids, Nonlinear Systems, Power Systems, Robotics, Social Systems, Economic Systems and other. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution and exposure which enable both a wide and rapid dissemination of research output.

The series covers the theory, applications, and perspectives on the state of the art and future developments relevant to systems and networks, decision making, control, complex processes and related areas, as embedded in the fields of interdisciplinary and applied sciences, engineering, computer science, physics, economics, social, and life sciences, as well as the paradigms and methodologies behind them.

More information about this series at http://www.springer.com/series/15179

P. Nagabhushan · D. S. Guru
B. H. Shekar · Y. H. Sharath Kumar
Editors

Data Analytics and Learning

Proceedings of DAL 2018

Springer

Editors
P. Nagabhushan
Indian Institute of Information Technology
Allahabad, Uttar Pradesh, India

D. S. Guru
Department of Computer Science
and Engineering, CBCS Education
University of Mysore
Mysuru, Karnataka, India

B. H. Shekar
Department of Studies in Computer Science
Mangalore University
Mangalore, Karnataka, India

Y. H. Sharath Kumar
Department of Information Science
and Engineering
Maharaja Institute of Technology
Belawadi, Karnataka, India

ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-981-13-2513-7 ISBN 978-981-13-2514-4 (eBook)
https://doi.org/10.1007/978-981-13-2514-4

Library of Congress Control Number: 2018954017

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

We write this message with deep satisfaction to the proceedings of the "First International Conference on Data Analytics and Machine Learning 2018 (DAL 2018)" held on March 30 and 31, 2018, at Mysore, Karnataka, India, which has the central theme "Data Analytics and its Application." Our research experiences in related areas for the last decade have inspired us to conduct DAL 2018. This conference was planned to provide a platform for researchers from both academia and industries where they can discuss and exchange their research thoughts to have better future research plans, particularly in the fields of data analytics and machine learning. Soon after we notified a call for original research papers, there has been a tremendous response from the researchers. There were 150 papers submitted, out of which we could accommodate only 50 papers based on the reports of the reviewers. Each paper was blindly reviewed by at least two experts from the related areas. The overall acceptance rate is about 30 %. The conference is aimed at image processing, signal processing, pattern recognition, document processing, biomedical processing, computer vision, biometrics, data mining and knowledge discovery, information retrieval and information coding. For all these areas, we got a number of papers reflecting their right combinations. I hope that the readers will appreciate and enjoy the papers published in the proceedings. We could make this conference a successful one, though it was launched at a relatively short notice. It was because of the good response from the research community and the good effort put in by the reviewers to support us with timely reviews. The authors of all the papers submitted deserve our acknowledgments. The proceedings are published and indexed by Springer-LNEE, which is known for bringing out this type of proceedings. Special thanks to them.

We would also like to thank the help of EasyChair in the submission, review, and proceedings creation processes. We are very pleased to express our sincere thanks to Springer, especially Jayanthi Narayanaswamy, Jayarani Premkumar, Aninda Bose, and the editorial staff, for their support in publishing the proceedings of DAL 2018.

Allahabad, India	Dr. P. Nagabhushan
Mysuru, India	Dr. D. S. Guru
Mangalore, India	Dr. B. H. Shekar
Belawadi, India	Dr. Y. H. Sharath Kumar

Contents

Editors and Contributors

About the Editors

P. Nagabhushan is Director of the Indian Institute of Information Technology, Allahabad, Uttar Pradesh. He has previously served as Professor at the University of Mysore and Amrita University. His areas of specialization are pattern recognition, digital image analysis and processing, document image analysis, and knowledge mining. He has published more than 500 papers in peer-reviewed journals and conferences in these areas. He has received research funding from various organizations, e.g., DRDO, MHRD, AICTE, ICMR, UGC, UGC, UPE, and SAP, and has more than 30 years of teaching experience.

D. S. Guru is Professor in the Department of Studies in Computer Science, University of Mysore. He completed his doctorate in computer science from the University of Mysore in 2000 and has published more than 200 research papers in national and international journals and conference proceedings. He has served as Program Chair for the 2009 International Conference on Signal and Image Processing in Mysore and is currently Reviewer for the International Journal of Pattern Recognition Letters, Journal of Pattern Recognition, Journal of Document Analysis and Recognition, Journal of Image and Vision Computing, and IEEE Transactions on Neural Networks.

B. H. Shekar is Professor in the Department of Studies in Computer Science, Mangalore University, India. His research interests include pattern recognition, image processing, database systems, and algorithms. He is an active researcher and has published more than 100 papers in peer-reviewed journals and conferences. He was granted a DST-DAAD Fellowship in 2002 and was the principal investigator for many research projects funded by DST-RFBR and UGC. He is also a member of many academic societies, e.g., the International Association for Pattern Recognition, IACSIT, and Indian Unit for Pattern Recognition and Artificial Intelligence.

Y. H. Sharath Kumar is Associate Professor in the Department of Information Science and Engineering, Maharaja Institute of Technology, Mysuru. He received his M.Tech. in 2009 and his Ph.D. in 2014, both from the University of Mysore. His research interests include image and video processing, pattern recognition, Sign Language Video Analysis, logo classification, biometrics, and precision agriculture. He has authored a number of papers in reputed journals and conference proceedings.

Contributors

Mostafa Ali Department of Studies in Computer Science, University of Mysore, Manasagangotri, Mysuru, Karnataka, India

Mokhtar A. Alworafi DoS in Computer Science, University of Mysore, Mysuru, India

R. Amarnath Department of Studies in Computer Science, University of Mysore, Mysuru, Karnataka, India

H. Annapurna Department of Studies in Computer Science, University of Mysore, Mysuru, Karnataka, India

C. V. Aravinda NMAM Institute of Technology NITTE, Karakal, Karnataka, India

Adela Arpitha DoS in Computer Science, University of Mysore, Mysuru, India

A. P. Ayshath Thabsheera Department of Computer Science, Central University of Kerala, Kasaragod, Kerala, India

Bharathlal Department of Studies in Computer Science, University of Mysore, Mysuru, India

Shabina Bhaskar Central University of Kerala, Kasaragod, Kerala, India

Nikitha Bhat Department of CSE, NMAM Institute of Technology, Nitte, India

Vikram Bhat Department of CSE, NMAM Institute of Technology, Nitte, India

Umesh P. Chavan School of Computational Sciences, Solapur University, Solapur, India

Venkatratnam Chitturi Department of Instrumentation Technology, GSSSIETW, Mysuru, India

Guesh Dagnew Department of Computer Science, Mangalore University, Karnataka, Mangalore, India

N. C. Dayananda Kumar Department of Electronics and Communication Engineering, Siddaganga Institute of Technology, Tumkur, India

Akshaya Devadiga NMAM Institute of Technology NITTE, Karakal, Karnataka, India

Atyaf Dhari College Education for Pure Science, Thi Qar University, Nasiriyah, Iraq

Rajesh K. Dhumal Department of CS and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India

R. Dinesh Department of Information Science and Engineering, Jain University, Bengaluru, India

Sheren A. El-Booz Department of Computer Science and Engineering, Menoufia University, Shibin El Kom, Egypt

Nagi Farrukh Faculty of Mechanical Engineering, Universiti Tenaga Nasional, Kajang, Selangor, Malaysia

D. S. Guru Department of Studies in Computer Science, University of Mysore, Manasagangotri, Mysuru, India

H. L. Gururaj Vidyavardhaka College of Engineering, Mysuru, India

Mallikarjun Hangarge Department of Computer Science, Karnatak Arts Science and Commerce College, Bidar, India

N. Harivinod Department of Computer Science and Engineering, Vivekananda College of Engineering and Technology, Puttur, Karnataka, India

Maryam Hazman Central Laboratory for Agricultural Experts Systems, Agricultural Research Center (ARC), Giza, Egypt

Ravindra S. Hegadi School of Computational Sciences, Solapur University, Solapur, India

G. Hemantha Kumar Department of Computer Science, University of Mysore, Mysuru, India; High Performance Computing Project, DoS in CS, University of Mysore, Mysuru, India

Swaroop Hople Veermata Jijabai Technological Institute, Mumbai, India

Mohammad Imran Department of Computer Science, University of Mysore, Mysuru, India

Mohammed Javed Department of IT, Indian Institute of Information Technology, Allahabad, Allahabad, India

V. K. Jyothi Department of Studies in Computer Science, University of Mysore, Manasagangotri, Mysuru, India

Karbhari V. Kale Department of CS and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India

V. N. Kamalesh VTU RRC, Belagavi, Karnataka, India; TJIT, Bengaluru, India

Saket Karve Veermata Jijabai Technological Institute, Mumbai, India

Thotreingam Kasar Kaaya Tech Inc., Mysuru, India

Mohammadamir Kavousi Southern Illinois University, Carbondale, USA

P. G. Lavanya DoS in Computer Science, University of Mysore, Mysuru, India

Suresha Mallappa DoS in Computer Science, University of Mysore, Mysuru, India

V. G. Manjunatha Guru GFGC, Honnāli, India; VTU RRC, Belagavi, Karnataka, India

K. S. Manjunatha Maharani's Science College for Women, Mysuru, Karnataka, India

N. Manohar Department of Computer Science, University of Mysore, Mysuru, India

K. Manoj Bengaluru, India

S. C. Mehrotra Department of CS and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India

N. Mohammed Muddasir Department of Information Science and Engineering, VVCE, Mysuru, India; NIE, Mysuru, India

Krishna Chaithanya Movva Indian Institute of Information Technology, Sri City, Chittoor, Andhra Pradesh, India

P. Nagabhushan Department of IT, Indian Institute of Information Technology, Allahabad, Allahabad, India

Ajay D. Nagne Department of CS and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India

Aida A. Nasr Department of Computer Science and Engineering, Menoufia University, Shibin El Kom, Egypt

Dattatray I. Navale School of Computational Sciences, Solapur University, Solapur, India

Tejas Nayak Department of CSE, NMAM Institute of Technology, Nitte, India

S. P. Paramesh Department of Studies in Computer Science and Engineering, U.B.D.T College of Engineering, Davanagere, Karnataka, India

Trupti D. Pawar School of Computational Sciences, Solapur University, Solapur, India

Bharathi Pilar Department of Computer Science, University College, Mangalore, Karnataka, India

H. N. Prakash Rajeev Institute of Technology, Hassan, Karnataka, India

J. Prathima Mabel Department of Information Science and Engineering, Dayananda Sagar College of Engineering, Bengaluru, India

Viswanath Pulabaigari Indian Institute of Information Technology, Sri City, Chittoor, Andhra Pradesh, India

K. Raghuveer Department of Information Science and Engineering, NIE, Mysuru, India

R. Rajesh Department of Computer Science, Central University of Kerala, Kasaragod, Kerala, India

K. N. Rama Mohan Babu Department of Information Science and Engineering, Dayananda Sagar College of Engineering, Bengaluru, India

B. Ramesh Malnad College of Engineering, Hassan, India

Radhika Rani SBRR Mahajana First Grade College, Mysuru, India

C. Rashmi High Performance Computing Project, DoS in CS, University of Mysore, Mysuru, India

Darshan D. Ruikar School of Computational Sciences, Solapur University, Solapur, India

Sepehr Saadatmand Southern Illinois University, Carbondale, USA

M. Shankar Lingam University of Mysore, Manasagangotri, Mysuru, India

B. Sharada Department of Studies in Computer Science, University of Mysore, Mysuru, India

Y. H. Sharath Kumar Department of Computer Science & Engineering and Department of Information Science, Maharaja Institute of Technology, Mandya, Karnataka, India

B. H. Shekar Department of Computer Science, Mangalore University, Mangalore, Karnataka, India

Vasisht Shende Veermata Jijabai Technological Institute, Mumbai, India

Sannidhi Shetty Department of CSE, NMAM Institute of Technology, Nitte, India

E. G. Shivakumar Department of Electrical Engineering, UVCE, Bangalore University, Bengaluru, India

K. S. Shreedhara Department of Studies in Computer Science and Engineering, U.B.D.T College of Engineering, Davanagere, Karnataka, India

G. S. Sindhushree Department of Studies in Computer Science, University of Mysore, Mysuru, Karnataka, India

A. M. Sudhakara University of Mysore, Manasagangotri, Mysuru, India

Mahamad Suhil Department of Studies in Computer Science, University of Mysore, Manasagangotri, Mysuru, Karnataka, India

D. S. Sunil Kumar Department of Computer Science, Mangalore University, Mangalore, Karnataka, India

H. D. Supreetha Gowda Department of Computer Science, University of Mysore, Mysuru, India

K. V. Suresh Department of Electronics and Communication Engineering, Siddaganga Institute of Technology, Tumkur, India

S. N. Sushma Department of Studies in Computer Science, University of Mysore, Mysuru, India

Seyedmahmoud Talebi Department of Computer Science, University of Mysore, Mysuru, India

T. M. Thasleema Department of Computer Science, Central University of Kerala, Kasaragod, Kerala, India

K. A. Vani Department of Information Science and Engineering, Dayananda Sagar College of Engineering, Bengaluru, India

C. Veershetty Department of Computer Science, Gulbarga University, Kalaburagi, India

B. T. Venu Gopal Department of Electrical Engineering, UVCE, Bangalore University, Bengaluru, India

Amol D. Vibhute Department of CS and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India

Recognition of Seven-Segment Displays from Images of Digital Energy Meters

Thotreingam Kasar

Abstract This paper describes a method to localize and recognize seven-segment displays on digital energy meters. Color edge detection is first performed on a camera-captured image of the device which is then followed by a run-length technique to detect horizontal and vertical lines. The region of interest circumscribing the LCD panel is determined based on the attributes of intersecting horizontal and vertical lines. The extracted display region is preprocessed using the morphological black-hat operation to enhance the text strokes. Adaptive thresholding is then performed and the digits are segmented based on stroke features. Finally, the segmented digits are recognized using a support vector machine classifier trained on a set of syntactic rules defined for the seven-segment font. The proposed method can handle images exhibiting uneven illumination, the presence of shadows, poor contrast, and blur, and yields a recognition accuracy of 97% on a dataset of 175 images of digital energy meters captured using a mobile camera.

Keywords Seven-segment displays · Character recognition
Camera-based document image analysis

1 Introduction

The camera provides a great opportunity for input from the physical world. In recent years, it has become hard to define the term document due to the blurring in the distinction between documents and user interfaces. In addition to imaging hard copy documents, cameras are now increasingly being used to capture text present on 3-D real-world objects such as buildings, billboards, road signs, license plates, black/whiteboards, household appliances, or even on a T-shirt which otherwise would be inaccessible to conventional scanner-based optical character recognition (OCR) systems. Pervasive use of handheld digital cameras has immense potential for newer applications that go far beyond what traditional OCR has to offer [1]. Recognizing

T. Kasar (✉)
Kaaya Tech Inc., Mysuru 570017, India
e-mail: kasar.kaayatech@gmail.com

P. Nagabhushan et al. (eds.), *Data Analytics and Learning*,
Lecture Notes in Networks and Systems 43,
https://doi.org/10.1007/978-981-13-2514-4_1

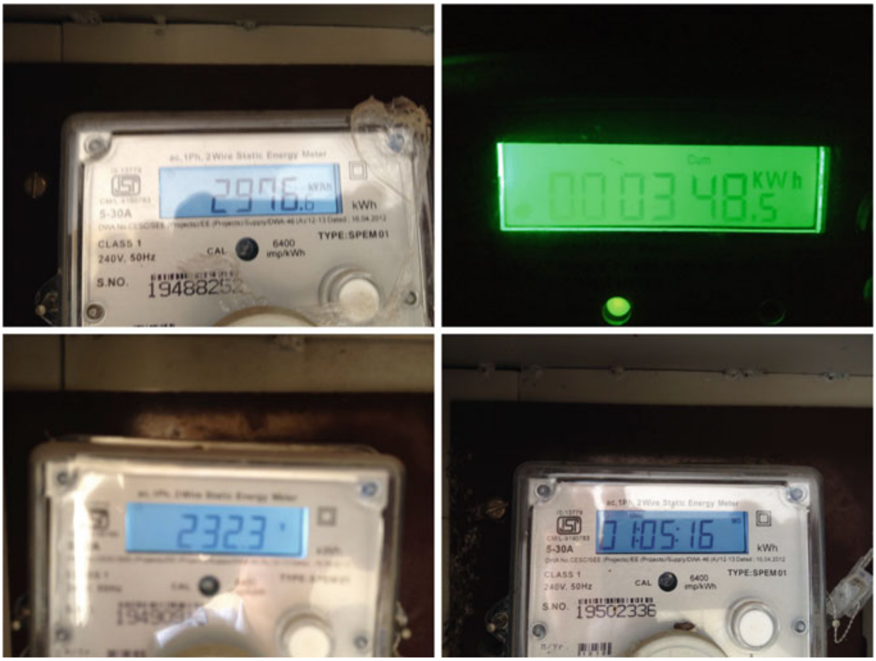

Fig. 1 Typical images of seven-segment displays on digital energy meters exhibiting uneven lighting, shadows, poor contrast, blur, and presence of highlights occluding parts of a digit

text in real-world scenes can be considered as an extension of current OCR technology widely available in the market. The unconstraint mode of document acquisition as well the difference in the target document type calls for a new level of processing for camera-captured images. While it may seem that the low variability of seven-segment displays should make them easy to read, its automatic detection and recognition is in fact a challenging task. A typical image of the display panel on an electronic device contains mostly background clutter and other irrelevant texts. Therefore, a preprocessing step of locating the display area is required before attempting to recognize text in the acquired image. Once the text region is localized, the subsequent recognition task can be performed only on the detected region of interest so as to obviate the effect of background clutter. However, the available technology is still far from being able to reliably separate text from the background clutter. In addition, images of LCD displays often exhibit poor contrast, blur, and may contain highlights and specular reflections from the display surface which make them hard to segment. Figure 1 shows some of these challenges commonly encountered in images of LCD displays.

2 Review of Related Work

While there are a lot of works on recognizing text from natural images [2–4], there has been relatively less work that address the specific problem of recognizing seven-segment displays on electronic devices. The Clearspeech system [5] requires special markers to be affixed to the device to guide the system in localizing the display panel. Shen and Coughlan [6] introduced a phone-based LED/LCD display reader, which do not have such modification of the display. They employ horizontal and vertical edge features in the image and extract the digits using a simple graphical model. Tekim et al. [7] improvized the method in [6] by adopting a connected-component-based approach to detect LED/LCD digits on a Nokia N95 mobile phone that can process up to 5 frames/s allowing the user to overcome issues such as highlights, glare, or saturation by simply varying the camera viewpoint. In [8], the authors address a method to recognize seven-segment displays on multimeters using binary edge and corner features. In this paper, a camera-based system is developed to detect and recognize seven-segment displays in digital energy meters. The method can be applied to images of several other electronic appliances such as calculators, digital blood pressure monitors, digital thermometers, microwave ovens, media players, etc. with minimal or no modification.

3 Proposed Method for Recognition of Seven-Segment Digits

This section describes the proposed method designed for the recognition of seven-segment displays from images of digital energy meters captured using mobile camera phones. The method involves two sub-tasks, namely, (i) localization of the LCD display area and (ii) recognition of the seven-segment digits in the localized area. The LCD display area is localized based on attributes of horizontal and vertical line segments and their intersection, while a support vector machine (SVM) is used for the classification of the digits. A schematic block diagram of the proposed method is shown in Fig. 2.

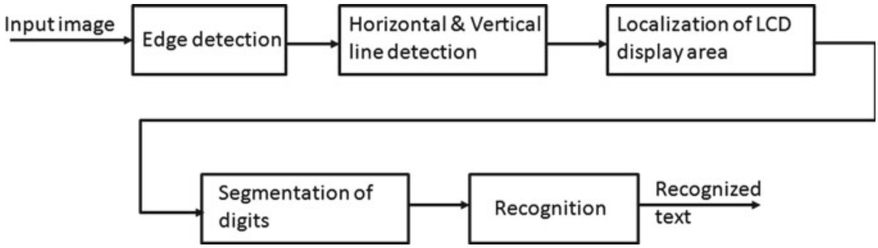

Fig. 2 Block diagram of the proposed seven-segment display recognition system

3.1 Determination of the LCD Display Area

Following image acquisition, the first task is to locate the LCD display area among substantial amounts of background clutter. To this end, Canny edge detection [9] is performed on each color channel of the captured image I. The overall edge map is obtained by taking the union of the individual edge images as follows:

$$E = E_R \cup E_G \cup E_B \quad (1)$$

where $\cup$ denotes the union operation. Following the method in [10], run-length count is performed on the resulting edge image E along the rows and columns to obtain the horizontal and vertical lines, respectively. If the number of runs of the edges starting at a pixel location exceeds a threshold value L, the segment is accepted as a line. Short line segments and other spurious lines with run-lengths less than the specified threshold value are not considered for further processing. The threshold L decides the shortest line that can be detected by the method. This parameter is adaptively set to a fractional proportion of the height of the image. It may be mentioned that the performance of the method is not sensitive to the choice of this parameter since the LCD display panel normally occupies a significant proportion of the image area. The union of the set of validated horizontal and vertical line segments obtained from the two directions yields a composite image I_L. Based on the positions of intersection of horizontal and vertical lines, their heights, and aspect ratios, the rectangular-shaped LCD display area is identified. This step of identifying the region of interest (ROI), i.e., the LCD display region, is an important processing module that removes the background clutter and returns only the relevant display region for further processing. The performance of this module is critical since it serves as the input for the subsequent digit recognition task and affects the overall performance of the system. It may be noted that the run-length method for horizontal and vertical line detection implicitly assumes that orientation of the image is not skewed. However, the method can tolerate a moderate skew angle of up to θ which is given by

$$\theta = \arctan(1/L) \quad (2)$$

For instance, if the minimum detectable line length L is set to eight pixels, the skew tolerance of the method is about $\pm 7.125°$. Thus, there is no strict requirement on the orientation of the camera viewpoint during image capture.

3.2 Segmentation of Digits

Once the ROI is located as described above, the area defined by the ROI is cropped off from the image. Since seven-segment LCD displays are represented in a darker shade with respect to that of the background, the strategy is to look for thin dark structures in the detected ROI. To enhance dark and thin line-like structures, the grayscale morphological bottom-hat operation is performed on the smoothed image obtained by Gaussian filtering the ROI.

$$I_p = (I_\sigma \bullet S_N) - I_\sigma \tag{3}$$

where $I_\sigma = I_g * G_\sigma$ with σ representing the variance of the Gaussian filter, I_g the grayscale image patch defined by the ROI and S_N is a square structuring element of size $N \times N$. The notations "$*$" and "$\bullet$" denote the 2-D convolution and the grayscale morphological closing operation, respectively. The Gaussian filter reduces the effect of noise and helps to maintain the continuity of narrow gaps between line segments. The variance σ of the Gaussian function controls the amount of smoothing. The bottom-hat operation enhances small dark structures while suppressing wide dark structures at the same time. The size N of the structuring element decides the maximum width of the line that can be detected by the system and is empirically set to 15 in this work. The method is not very sensitive to the choice of this parameter and it may be altered without any significant effect on the overall performance.

This intermediate image I_p is then thresholded using a fast implementation of the Niblack's method [11] using integral images [12]. At each pixel location (x, y), the mean $\mu(x, y)$ and the standard deviation $\sigma(x, y)$ within a window $W \times W$ are computed and the gray level at that pixel location is compared with the threshold value $T(x, y)$ given by the following expression:

$$T(x, y) = \mu(x, y) - k\sigma(x, y) \tag{4}$$

The window of size is set to $h/5 \times w/5$ where h and w denote the height and width of the detected ROI, respectively, and the parameter k is set to 0.2. Since the segments of a seven-segment character are not connected, we need to group the individual segments to form the digits before feature extraction and recognition. An eight connected component (CC) labeling is performed on the resulting binary image. Components that touch the image boundary are discarded since it is generally a part of the background. The stroke widths of the remaining CCs are computed using a combination of the distance transform and the skeleton of the CC obtained using a fast thinning algorithm proposed by Zhang and Suen [13]. The maximum stroke width D_{max} is then determined which is used to group the CCs into digits by performing a closing operation with square structuring of size $2D_{max} \times 2D_{max}$. One further step of CC labeling is performed on the resulting image and the bounding box attributes are computed. Since the digits in LCD displays are of similar heights and located horizontally next to each other, the candidate digits are obtained by imposing the height similarity and spatial regularity of the CCs. These filtered CCs are then passed onto the recognition module.

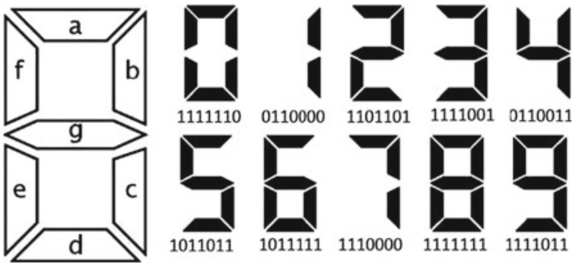

Fig. 3 The seven-segment font and the code (abcdefg) for each digit from 0–9 in terms of its ON/OFF states of the individual segments

3.3 Digit Recognition

Figure 3 depicts a typical seven-segment display unit, where any digit can be represented by a 7-bit code depending on the ON or OFF state of the individual segments a, b, ..., g. Since seven-segment displays have a fixed font style, a simple digit recognizer may be formulated based on syntactic rules to recognize the 10 digits [0 1 2 3 4 5 6 7 8 9]. However, such deterministic rules may not work well in practice due to segmentation errors and noise. Here, in this work, an SVM classifier trained on a collection of 500 digits is used. For each segmented CC, the proportion of ON pixels within an area defined by each of individual segments is measured. From seven such measurements over each of the areas defined by the seven segments, a seven-dimensional feature vector is obtained from each candidate CC which is then classified using the trained SVM classifier. While the aspect ratio (width/height) for each digit is around 0.5, the same parameter is much smaller for the digit 1 and hence it can be easily identified. Whenever the aspect ratio of the test CC is less the 0.4, feature extraction is done only for the segments b and c and assign 0 for all the other segments.

3.3.1 Identification of Dots

As a post-processing step, the area within the recognized digits is examined in the presence of dots. Identification of a dot is based on the size and aspect ratio of the CCs. Any small CCs that lie between two segmented digits are separately processed to determine if it is a dot or not. If the size of such a CC is less than t_1 times πD_{max}^2 (t_1 is a scalar, set to 1.5 in this work) and its aspect ratio is close to 1, it is considered as a dot.

3.4 Experimental Results

To test the performance of the system, 175 images of energy meters are captured using Apple iPhone 4S and Tinno S4700. These images are captured from a distance

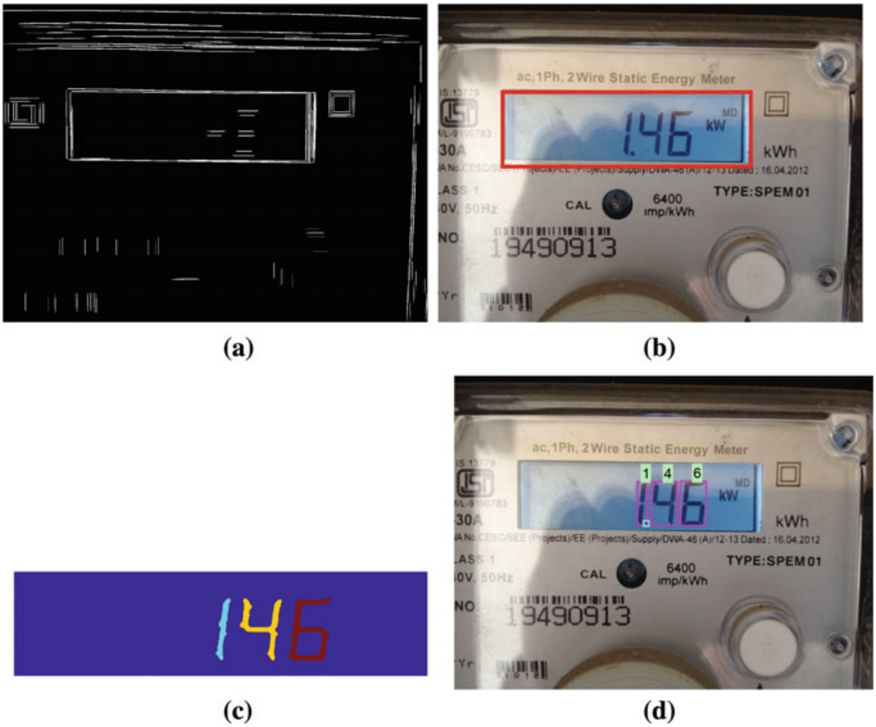

Fig. 4 Intermediate results of the proposed method on a sample test image **a** Detection of horizontal and vertical line segments **b** Localization of the LCD display area **c** Segmentation of the digits **d** Final results of recognition. Note that the decimal point indicated by the cyan rectangle is also identified thereby achieving a correct recognition of the value of the reading on the device

of about 15 to 30 cms from the device and ensuring that the orientation of the captured image is roughly horizontal. However, there is no strict requirement for the position and orientation of the camera viewpoint during image capture. The low and high threshold parameters of the Canny edge detection are set to 0.1 and 0.2, respectively, while the variance of the associated Gaussian function is set to 2. The parameter L for horizontal and vertical line segment detection is adaptively set to 1/30 times the height of the image. Since the LCD display panel of the device is rectangular with a fixed aspect ratio (between 3 to 4), the display area can be identified by subjecting each pair of intersecting horizontal and vertical lines to an aspect ratio test and additionally a lower bound on the length of the vertical line segment to filter out small candidate regions. Whenever there is a detection of nested regions, the overall bounding rectangle of all the detected regions is considered to be the ROI. Following the localization of LCD display area, a preprocessing step of Gaussian smoothing and grayscale morphological black-hat operation is performed to enhance the segments of the seven-segment characters. While conventional thresholding techniques fail to accurately extract the digits, the black-hat operation enables reliable digit

Fig. 5 Representative results of the proposed method. The segmented digits are represented in terms of the bounding boxes and the corresponding recognized results are overlaid above each digit. The method can handle images exhibiting uneven illumination, the presence of shadows, poor contrast, and blur

segmentation even under poor contrast and uneven lighting. Because of the fixed structure of seven-segment font, the SVM classifier can reliably recognize the segmented digits, even when there are instances of one segment segmentation error. Figure 4 shows the intermediate results of various processing stages on a sample test image. It may be noted that the presence of the dot between the first digit 1 and the second digit 4 is also identified that is necessary to infer the correct reading of the display.

Figure 5 illustrates the robustness of the proposed method to uneven lighting, the presence of shadows, low contrast, and blur. The method works well for most images captured under typical imaging conditions. It can also tolerate moderate skew as is evident from the last image of the figure. An overall recognition accuracy of 97% is achieved on a collection of 175 test images. Glare, highlights, and poor contrast are the main sources of recognition error while excessive blur can affect the accuracy of edge detection and consequently the localization of the ROI.

3.5 Conclusions and Future Work

This paper describes a new method to recognize seven-segment displays from images of energy meters captured using a mobile camera. The LCD panel area is determined based on the properties of intersecting horizontal and vertical lines. The morphological black-hat operation enables robust segmentation of the digits even under poor contrast and uneven lighting. The proposed method yields a high performance for images captured under typical imaging conditions and even though the size of dataset used for the evaluation is small, the method is expected to yield a consistent performance on larger test sets too. However, like any other method, it is sensitive to specular highlights, severe blurring, and saturation. The quality of images of LCD displays varies greatly depending on the ambient environment and on the position of the acquisition camera relative to the display. It was observed that glare and reflections that may occlude the digits in the display can be avoided by changing the camera viewpoint. Thus, to address these challenges, the method may be augmented with a continuous feedback system to update the result of recognition to the user in real time. Based on this visual feedback, the user can vary the position the acquisition camera till a perfect recognition is achieved. Such an approach will make it possible to read displays on modern electronic appliances in real time and can lead to a host of new applications.

References

1. Liang, J., Doermann, D., Li, H.: Camera-based analysis of text and documents: a survey. Int. J. Doc. Anal. Recognit. **7**, 83–200 (2005)
2. Wang, K., Babenko, B., Belongie, S.: End-to-End scene text recognition. In: International Conference on Computer Vision, pp. 1457–1464 (2011)

3. Neumann, L., Matas, J.: Real-Time Scene Text Localization and Recognition. In: International Conference on Computer Vision and Pattern Recognition, pp. 3538–3545 (2012)
4. Wang, T., David J. W., Coates, A., Andrew Y. Ng.: End-to-End Text Recognition with Convolutional Neural Networks In: International Conference on Pattern Recognition, pp. 3304–3308 (2012)
5. Morris, T., Blenkhorn, P., Crossey, L., Ngo, Q., Ross, M., Werner, D., Wong, C.: Clearspeech: a display reader for the visually handicapped. IEEE Trans. Neural Syst. Rehabil. Eng. **14**(4), 492–500 (2006)
6. Shen, H., Coughlan, J.: Reading LCD/LED displays with a camera cell phone. In: Conference on Computer Vision and Pattern Recognition Workshop (2006)
7. Tekim, E., Coughlan, J. M., Shen, H.: Real-Time Detection and Reading of LED/LCD Displays for Visually Impaired Persons. In: Workshop Applications of Computer Vision, pp. 181–184 (2011)
8. Rakhi, P. G., Sandip P. N., Mukherji, P., Prathamesh M. K.: Optical character recognition system for seven segment display images of measuring instruments. In: IEEE Region 10 Conference on TENCON, pp. 1–6 (2009)
9. Canny, J.: computational approach to edge detection. IEEE Trans. Pattern Anal. Mach. Intell. **8**(6), 679–698 (1986)
10. Kasar, T., Barlas, P., Adam, S., Chatelain, C., Paquet, T.: Learning to detect tables in scanned document images using line information. In: International Conference on Document Analysis and Recognition, pp. 1185–1189 (2013)
11. Niblack W.: An Introduction to Digital Image Processing. Prentice Hall (1986)
12. Shafait, F., Keysers, D., Breuel, T.M.: Efficient implementation of local adaptive thresholding techniques using integral images. SPIE Electron. Imaging **6815**, 10 (2008)
13. Zhang, T.Y., Suen, C.Y.: A fast parallel algorithm for thinning digital patterns. Commun. ACM **27**(3), 236–239 (1984)

An Enhanced Task Scheduling in Cloud Computing Based on Hybrid Approach

Mokhtar A. Alworafi, Atyaf Dhari, Sheren A. El-Booz, Aida A. Nasr, Adela Arpitha and Suresha Mallappa

Abstract Quality of Services (QoS) has become a more interested research point in cloud computing from the perspectives of cloud users and cloud service providers. QoS mainly concerns minimizing the total completion time of tasks (i.e., makespan), response time, and increasing the efficiency of resource utilization. One of the most investigated techniques to meet QoS requirements in the cloud environment is adopting novel task scheduling strategies. Based on our studies, we found that existing solutions neglect the difference in efficiency of resource performance or the starved processes, which can strongly affect the scheduling solution outcome. In this paper, we consider this difference and propose a Hybrid-SJF-LJF (HSLJF) algorithm, which combines Shortest Job First (SJF) and Longest Job First (LJF) algorithms, while considering the load on resources. To start with, the algorithm sorts the submitted tasks in ascending order. Next, it selects one task according to SJF and another according to LSF. Finally, it selects a VM that has minimum completion time to execute the selected task. The experimental results indicate the superiority of HSLJF in minimizing the makespan, response time, and actual execution time while increasing the resource utilization and throughput when compared to the existing algorithms.

M. A. Alworafi (✉) · A. Arpitha · S. Mallappa
DoS in Computer Science, University of Mysore, Mysuru, India
e-mail: mokhtar119@gmail.com

A. Arpitha
e-mail: adelaarpitha23@gmail.com

S. Mallappa
e-mail: sureshabm20@gmail.com

A. Dhari
College Education for Pure Science, Thi Qar University, Nasiriyah, Iraq
e-mail: atyafcomsinc@gmail.com

S. A. El-Booz · A. A. Nasr
CSE, Menoufia University, Shibin El Kom, Egypt
e-mail: eng.sheren1975@gmail.com

A. A. Nasr
e-mail: aida.nasr2009@gmail.com

P. Nagabhushan et al. (eds.), *Data Analytics and Learning*,
Lecture Notes in Networks and Systems 43,
https://doi.org/10.1007/978-981-13-2514-4_2

Keywords Quality of service · Cloud computing · Makespan · Response time
HSLJF

1 Introduction

Cloud computing is the computing paradigm built above many former computing models, such as distributed computing, cluster computing, utility computing, and autonomic computing, which is considered as an advanced step to grid computing model. Cloud computing allows accessing of a wide range of shared resources which exists in data centers. The benefit of such resources is achieved via virtualization [1], which is the backbone of cloud computing. A Virtual Machine (VM) is created with the resources required for each user's tasks where these tasks will be implemented on this VM [2]. The resources of the cloud computing environment can be shared among the VMs (like processing cores and memory). These resources are offered for each VM based on total available processing power in the cloud [3]. These resources receive a huge amount of demand for tasks coming from different places in the world. So, each cloud needs a scheduling strategy in order to determine and process the execution order of the tasks [4]. Therefore, such a huge conglomeration of tasks and resources, shared among users on subscription basis [5], generates one of the main challenges and a hot scope for research called scheduling issue [6]. Scheduling is the process responsible for assigning tasks submitted to suitable resource provision. There are several objectives related to task scheduling algorithms which can be considered in designing the scheduling algorithm such as minimizing fairness, makespan, reducing energy consumption, minimizing cost, minimizing response time, and so on [2]. In general, there are various task scheduling algorithms utilized in cloud, such as Round Robin, which is a simple algorithm depending on the quantum time concept, meaning the time is portioned into intervals and each VM is given a time interval. The VM will execute its tasks based on this quantum. This algorithm does not consider the load and it selects the resources randomly [7]. Shortest Job First (SJF) is another algorithm in cloud computing, which takes into account the length of task where the tasks are sorted in ascending order, whereas Longest Job First (LJF), the opposite of SJF algorithm orders the tasks in descending order [8]. But both algorithms suffer from the starvation problem, which is one of the main problems that face task scheduling in cloud computing where the task may have to wait for a very long time to get its requested resources served [9].

None of the above algorithms is perfect. Some of these algorithms do not consider the length of the task or the load on resources, while others suffer from starvation. Hence, in this paper, we try to overcome these issues by proposing a Hybrid-SJF-LJF (HSLJF) scheduling algorithm. It fulfills the gaps formed in previous scheduling algorithms. In our proposed HSLJF algorithm, we consider the length of the task and the load on each resource. It will first assign the shortest task followed by the longest. For each task, the load on available resources is calculated and the task will be assigned to resource which has less completion time, and when there is more than one resource returning the same completion time, the resource which has the largest computing processor is selected for maximizing the resource utilization that enhances the system performance. The experimental results demonstrate that the proposed HSLJF algorithm minimizes the total completion time of tasks (makespan), response time, and the actual execution time of each task while maximizing the resource utilization and throughput when compared to the existing algorithms.

The structure of our paper is organized as follows: Sect. 2 presents the related work. Section 3 introduces the system model of scheduling. The proposed algorithm is discussed in Sect. 4. Additionally, we present the simulation environment in Sect. 5. In Sect. 6, the performance evaluation is presented. Finally, Sect. 7 concludes our proposal.

2 Related Work

Elmougy et al. [9] proposed a hybrid task scheduling algorithm called (SRDQ), which combines Shortest Job First (SJF) and Round Robin (RR) algorithms using a dynamic changing task quantum to balance waiting time between short and long tasks. Also, the ready queue is divided into two queues: the first queue includes the short tasks, while the long tasks are put in the second queue. SRDQ assigns two tasks from the first queue followed by another task from the second queue. The simulation results demonstrated that their algorithm outperformed SJF, RR, and Time Slicing Priority Based RR (TSPBRR) algorithms by minimizing the tasks' response time and waiting time, with partly the long tasks being starved.

Yeboah et al. [10] enhanced Round Robin algorithm with Shortest Job First algorithm (RRSJF). This proposal selected the processes depending on the shortest job first in a round robin concept to get optimal selection of job. CloudSim toolkit simulator was used for evaluating the performance of the proposed algorithm and the experimental results proved that their proposed algorithm outperformed Round Robin by minimizing average waiting time, average turnaround, and context switches.

Authors in [11] presented a hybrid algorithm which combined the Shortest Job First and priority scheduling algorithms for reducing the waiting time and response time in addition to turnaround time. The proposed hybrid algorithm solved the problem of deadlock or congestion or increase in latency and enhanced the resources' performance of cloud by reducing the latency and communication overhead.

Suri and Rani [12] introduced three phases in their scheduling algorithm model namely minimization, grouping, ranking, and execution. They took into account some parameters that influenced the algorithm's performance such as average waiting time, makespan, completion time, and turnaround time. The task execution is to have normal distribution and exponential distribution. The tasks were ranked depending on the concept of Shortest Job First algorithm (SJF). The experimental results proved that their proposed algorithm was better than First Come First Serve (FCFS) and the Largest Processing Time First (LPTF) algorithms in improving the defined performance parameters.