EVOLUTION IN ELECTRICAL AND ELECTRONIC ENGINEERING
e-ISSN: 2756-8458

EEEE

Vol. 5 No. 1 (2024) 487-496
https://publisher.uthm.edu.my/periodicals/index.php/eeee

Remote Monitoring System for Electricity Meter using ESP32CAM and OCR Analysis using MATLAB

Mochammad Safii Mochammad Shaleh[1], Chia Kim Seng[1,2*]

[1] *Faculty of Electrical and Electronic Engineering, Universiti Tun Hussien Onn Malaysia, Batu Pahat, 86400, MALAYSIA*

[2] *Microelectronics and Nanotechnology Shamsuddin Research Centre (MiNT-SRC), Universiti Tun Hussien Onn Malaysia, Batu Pahat, 86400, MALAYSIA*

*Corresponding Author: kschia@uthm.edu.my
DOI: https://doi.org/10.30880/eeee.2024.05.01.061

Article Info

Received: 11 January 2024
Accepted: 11 March 2024
Available online: 30 April 2024

Keywords

ESP32CAM, OCR Analysis, Remote Monitoring, Electricity Meter

Abstract

The increasing demand for effective and intelligent energy management systems has prompted the advancement of sophisticated technologies for the real-time monitoring of electricity usage. This study introduces a Remote Monitoring System that utilizes the ESP32CAM microcontroller and employs Optical Character Recognition (OCR) analysis to offer a comprehensive solution for remotely monitoring electricity meters. The system utilizes the ESP32CAM microcontroller, known for its power and versatility, to capture periodic images of electricity meters. Subsequently, OCR analysis is applied to extract numerical data, such as meter readings, from the captured images, enhancing automation and accuracy while minimizing manual intervention. Key elements of the proposed system encompass an ESP32CAM module equipped with a camera for image capture, integrated wireless connectivity for remote communication, and OCR algorithms for efficient data extraction. The system is designed to be adaptable, accommodating various types of electricity meters commonly found in residential, commercial, and industrial settings. The capabilities of remote monitoring empower users to access real-time data on electricity consumption through a user-friendly interface, facilitating informed decisions regarding energy management. Moreover, the system has the potential for proactive maintenance by notifying users of irregularities or anomalies in electricity consumption patterns. The suggested Remote Monitoring System offers a cost-effective and scalable solution to enhance the efficiency of electricity consumption monitoring. By amalgamating the features of ESP32CAM and OCR analysis, this system establishes a dependable platform for remote monitoring, contributing to the progression of intelligent and sustainable energy management practices.

1. Introduction

In a period characterized by escalating energy needs and a growing focus on eco-friendliness, the demand for cutting-edge technologies in the field of energy monitoring and management has become crucial. This endeavor focuses on creating a Remote Monitoring System for Electricity Meters, utilizing the capabilities of the ESP32CAM microcontroller and incorporating Optical Character Recognition (OCR) analysis. Traditional techniques for reading electricity meters often entail manual procedures that are time-intensive and prone to errors. The deployment of the ESP32CAM, renowned for its adaptability and connectivity, acts as a pivotal technological foundation, facilitating smooth data acquisition and transmission. The inclusion of OCR analysis further enhances the system's capabilities, enabling the precise extraction and interpretation of meter readings. This work not only tackles the inefficiencies linked to conventional metering methods but also aligns with broader objectives centered on advancing smart grid technologies. The execution of this system has the potential to transform the approach to monitoring and overseeing electricity consumption, fostering a more sustainable and adaptable energy infrastructure for the future. Optical Character Recognition (OCR) has the potential to offer remote measurement capabilities for traditional utility meters such as water, natural gas, and electricity. It can be considered a cost-effective enhancement for the functionality of these meters, extending their operational lifespan [1]. Remote monitoring involves overseeing and managing a local computer from a network system, encompassing tasks like collecting data, monitoring, and performing maintenance remotely. Various methods for real-time data collection and processing are essential in the remote monitoring system, often incorporating an embedded database. The independence of data and programs allows for efficient sharing of activities, such as data access and queries [2]. Optical Character Recognition (OCR) is a predominant aspect to transmute scanned images and other visuals into text. Computer vision technology is extrapolated onto the system to enhance the text inside the digitized image. In a paramount manner, image pre-processing techniques like black and white, inverted, noise removal, grayscale, thick font, and canny are applied to escalate the quality of the picture [3]. Optical character recognition (OCR) is sometimes referred to as text recognition. An OCR program extracts and repurposes data from scanned documents, camera images and image-only pdfs. OCR software singles out letters on the image, puts them into words and then puts the words into sentences, thus enabling access to and editing of the original content. It also eliminates the need for manual data entry [4].

2. Design and Method

The system requirements are organized into three phases, depicted in Fig. 1. The initial stage of phase one involves compiling a hardware list for sensor development within the planning process. Essential information will be gathered by reviewing pertinent papers, websites, and literature to ensure comprehensive coverage of the necessary components.

The hardware will be built in phase two by constructing circuits based on the parameters. Following that, the hardware will be adjusted to suitable settings, and performance of OCR process will be shown in the output result.

Phase three will involve building the simulation utilising the ESP32CAM module and transferring the captured images into MATLAB software for OCR analysis. The data analysis will be documented in a table to monitor the accuracy of the OCR process performance.

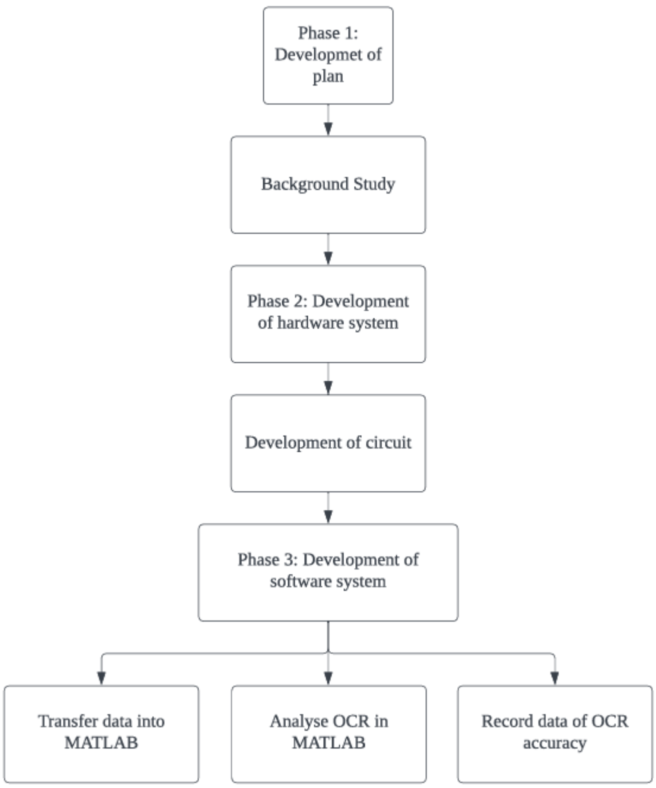


Fig 1 *General steps of the methodology*

2.1 Circuit Design for Remote Monitoring System

Fig. 2 illustrates the circuit diagram detailing the connection between the ESP32CAM and the FTDI adapter. Table 1 outlines the pin connections of each component from the FTDI adapter to the ESP32CAM module. To enable programming mode, connections are established from pin GPIO0 to ground GND on the ESP32CAM. Subsequently, for serial communication from the Arduino IDE to the ESP32CAM module, connections are made from UOT pin to the RX pin and UOR pin to the TX pin on the FTDI adapter. Following this, the 5V pin is linked to the VCC pin for power supply, and the GND pin is connected to the GND pin on the FTDI adapter to ensure proper grounding.

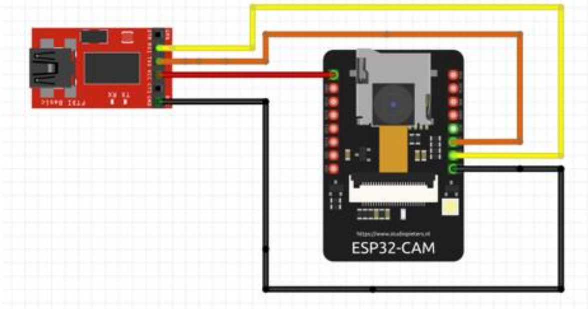


Fig 2 *Circuit diagram connection of the ESP32CAM and FTDI Adapter*

Table 1 *ESP32CAM Pin Connection*

Component	Connection
ESP32CAM	"5V" > "VCC" FTDI Converter "GND" > "GND" FTDI Converter "UOT" > "RX" FTDI Converter "UOR" > "TX" FTDI Converter

2.2 ESP32CAM Snapshot

ESP32CAM module snapshots are carried out by accessing through the IP address generated in ARDUINO IDE after running the coding for the hardware which can be accessed through web browser through devices such as smartphones, laptops, and personal computers. Fig. 3 shows the IP address generated by the ARDUINO IDE for the ESP32CAM module while Fig. 4 shows the interface for the livestream and snapshot reading from the ESP32CAM module view from smartphone.

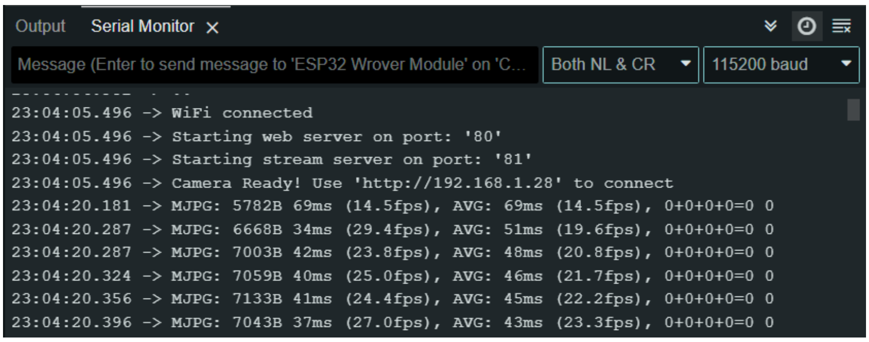


Fig 3 *IP Address for ESP32CAM module generated from Arduino IDE*

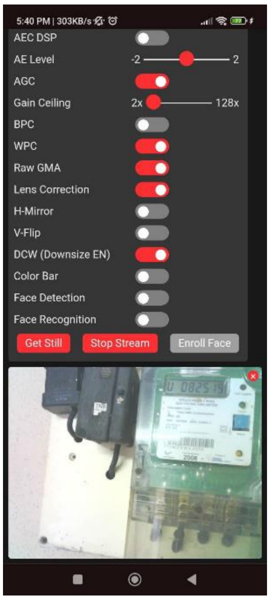


Fig 4 *ESP32CAM interface stream and snapshot on smartphone*

3. Results and Discussion

3.1 OCR Performance and Analysis

The OCR performance and analysis were conducted using picture snapshots taken by the ESP32CAM. The images then are transferred to the MATLAB coding scripts to be processed into grayscale image view which then the OCR performance and accuracy results will be analyzed. The OCR results are divided into three portions accordingly: the original picture, the initial mask, and the final mask. In theory, if the distance between the ESP32CAM module placement on electricity meter are reduced when reading capture are recorded, the results for the final mask OCR analysis should be clearer and more visible. However, factors such as image quality, lens specifications, camera calibration, text font and size, environmental conditions, and other conditions all play a role in the OCR performance and analysis.

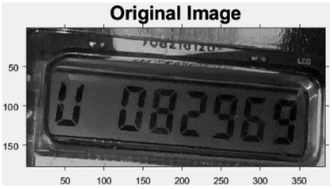
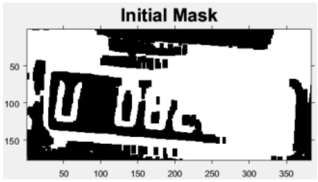
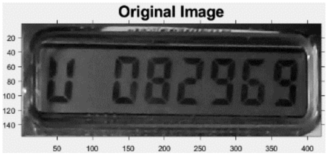
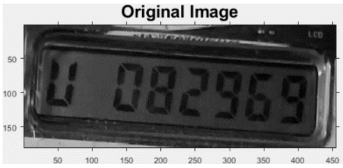
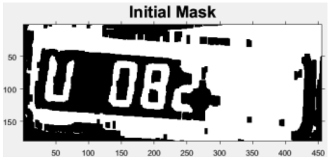
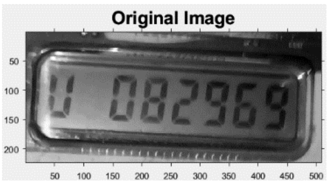
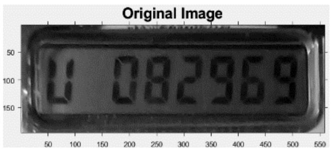
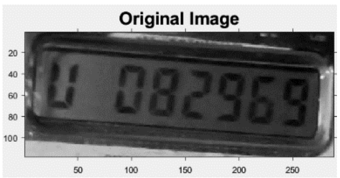
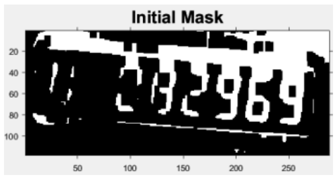
3.1.1 OCR Analysis for Original Image versus Initial Mask

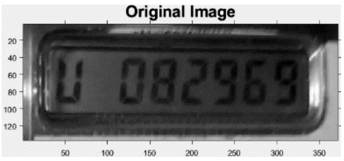
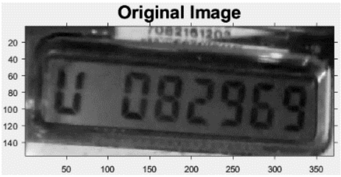
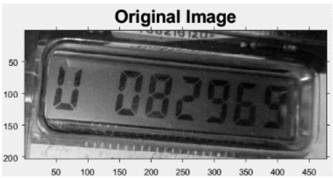
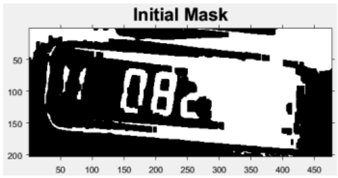
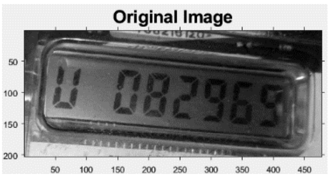
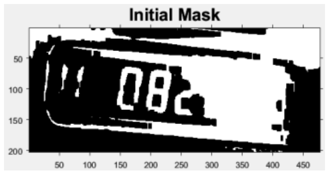
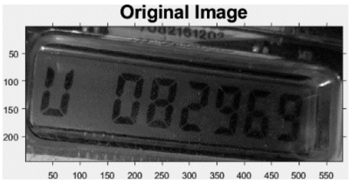
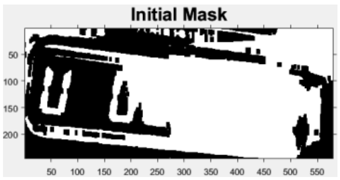
In this section, we will discuss the original image versus initial masking analysis conducted on the ESP32CAM reading captures to evaluate the performance of the constructed prototype. The reference reading used, starting from left to right, corresponds to a value of “**U 082969”** displayed on the electricity meter as shown in Table 2.

During the initial reading capture at 28 cm, the OCR process with the initial mask reveals results for the character ‘U 08’. However, visibility gradually decreases, where only the lower half of the value ‘2’ is visible. At 26 cm, the OCR process yields visible results, covering the character **‘U 082969’**. Moving on to 24 cm, the OCR process shows results within the value for **‘U 082’** being visible while the value **‘969’** is not visible. At 22 cm, the initial mask OCR result is not visible for the character **‘U 08’**, and the value **‘2’** is only visible for the top half portion, while the value **‘969’** is visible. At 20 cm, the initial mask OCR process yields results back to a much clearer view same as at 26 cm distance with character value **‘U 082969’**.

Continuing at 18 cm, the initial mask OCR process results in a visibility decrease for the **‘U08’** character, then slowly increases for the **‘2969’** character value in contrast and sharpness, which started to occur at the 20 cm distance, and then it begins to restore its shape for the value **‘969’**. At 16 cm, visibility for the **‘U 082’** character decreases in contrast and sharpness, but it starts to restore to its normal state for the character value **‘969’**. At 14 cm, gradually the **‘U08’** character size is expanding, and at **‘2969’**, the character value becomes more visible in size and with increased contrast. At distances of 12 cm and 10 cm, the **‘U 082’** character is visible, but the **‘2’** character is gradually becoming less visible, while the values for **‘969’** gradually fade away. Finally, at 8 cm, the **‘U 0’** character is visible, then slowly fades away the visibility for character values of the **‘82969’**.

Table 2 *ESP32CAM Original Image vs. Initial Mask*

Distance (cm)	Original Image	Initial Mask OCR
28		
26		
24		
22		
20		
18		

16		
14		
12		
10		
8		

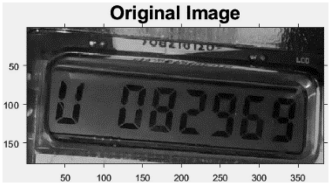
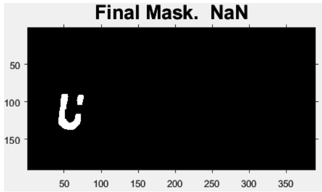
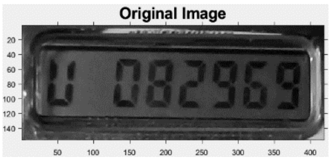
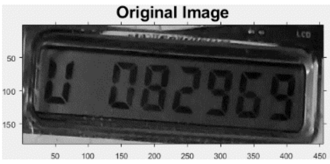
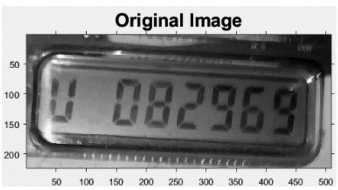
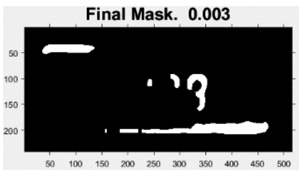
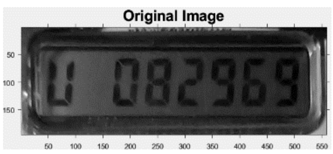
3.1.2 OCR Analysis for Original Image versus Final Mask

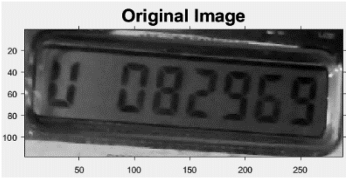
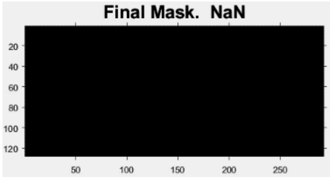
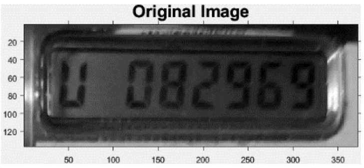
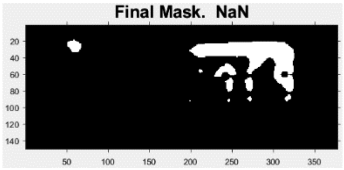
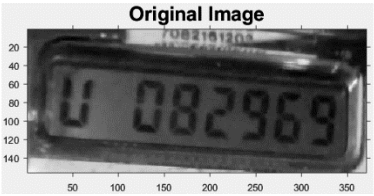
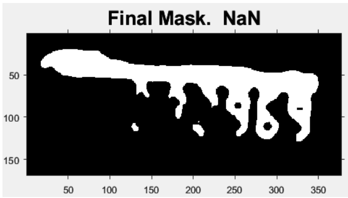
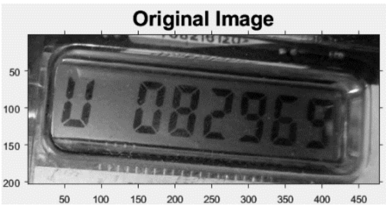
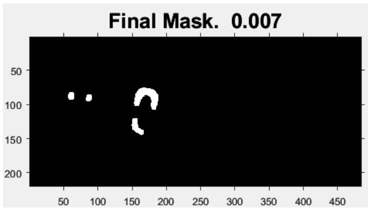
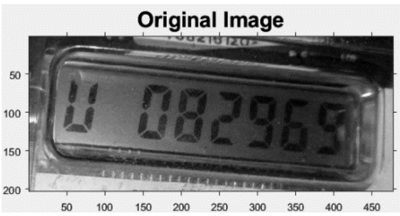
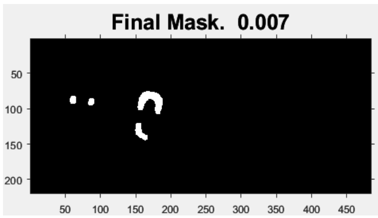
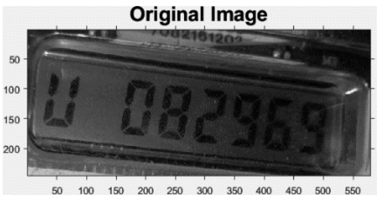
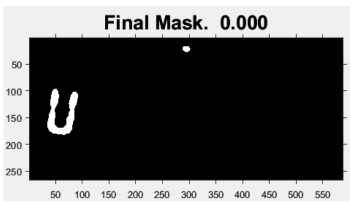
In this section, we will discuss the original image versus final masking analysis conducted on the ESP32CAM reading captures to evaluate the performance of the constructed prototype. The reference reading character used is the same as initial masking, starting from left to right, corresponding to a value "U 082969" displayed on the electricity meter as shown in Table 3.

During the initial reading capture at a distance of 28 cm, the OCR process, when applied with the final mask, reveals results that are only visible for the character 'U'. Moving closer to 26 cm, the OCR process produces visible results covering the character 'U 0829'. Continuing the approach at 24 cm, the OCR process displays results within the value for 'U08', while the value '2969' is not present. At 22 cm, the final mask OCR result is not visible for 'U08', only for the first left side 9-character value within the x-axis position scale range of 320 to 350 is visible. This achieves about 80% progress in the OCR process, and the value '69' at the x-axis position scale range between 360 and 450 is absent. Within this range, the characters 'U08' at x-axis position scale range between 40 and 250 are not visible, and the 2-character value is only minimally visible in a small portion.

At 20 cm, the final mask OCR process produces results within the x-axis scale range of 50 to 520. For the value 'U0', it is partially present, while for '82', it is fully visible. Reducing the distance to 18 cm, the final mask is absent, and at 16 cm, it becomes visible at the x-axis position scale range between 200 and 330 for the value '969', covering only a partial segment of the character. At 14 cm, the OCR result becomes least achievable for the value '82' while for character value '969' within the x-axis position scale range of 130 to 340, displaying an increasing pattern for the OCR segment result. At distances of 12 cm and 10 cm, the final mask yields the same outcome, with the value 'U0' present at the x-axis position scale range between 60 and 180. Lastly, at 8 cm distance, the final mask result appears for the value 'U' at the x-axis position scale range between 40 and 90.

Table 3 *ESP32CAM Original Image vs. Final Mask*

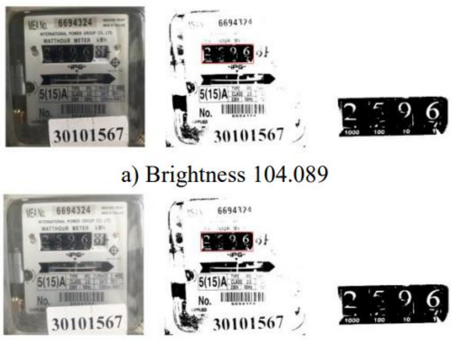
Distance (cm)	Original Image	Final Mask OCR
28		
26		
24		
22		
20		

18		
16		
14		
12		
10		
8		

3.2 Comparative Analysis of Research Findings

The research findings have been compared to a study conducted by Rungaroon Khunsamitpanya, Rangsiman Yotsongpol, Sharunya Srichanpliuw, and Chanchai Techawatcharapaikul, which investigate the OCR accuracy test results is influenced by factors of brightness range in Fig. 5 in terms of brightness settings, the established range was between 0 to 255, and the most successful OCR outcomes were noted at brightness levels of 104.089 and 221.319. Their study also utilized distance range from 0 to 20 cm as in Fig. 6, with the most optimal results achieved at distances of 8 cm and 12 cm using their devised algorithm. and image orientation in Fig. 7 [5].

In comparison, the results taken for this work reveal that reading taken under specific distance, brightness, contrast, and other ESP32CAM capture settings resulted in a more favorable OCR accuracy performance. For the initial mask as shown in Table 2, The distance that provided the clearest OCR result from this project with proper setting is at 26 cm with characterization by segment for the 'U 082969' character value. Distance 8 cm yields the least clear OCR result, displaying just the characterization segment for the 'U 0' character value. In terms of the final masking referred to in Table 3, the distance that provided the clearest OCR result from this project with an appropriate setting is 26 cm in terms of characterization by segment for 'U 0829' character value view from the original reference character value at 'U 082969'. The least clear OCR result is obtained at 18 cm, which does not reveal any character value at all for the final masking.



a) Brightness 104.089

b) Brightness 221.319

Fig. 5 *Detection Test Results regarding Brightness*

a) 8 cm. b) 12 cm.

Fig. 6 *Detection Test Results regarding Distance*

Fig. 7 *Detection Test Results regarding Orientation*

4. Conclusion

In conclusion, the OCR analysis performed with the ESP32CAM at various setup distances provided useful insights into the system's performance in various spatial configurations. The findings show that the distance between the ESP32CAM and the target text has a considerable impact on the accuracy and reliability of the optical character recognition process. As the distance between the OCR system and the electricity meter decreases, difficulties such as diminished picture quality and probable degradation of text readability occur, reducing the system's overall efficiency. Finding an ideal setup distance is obviously critical for maximizing OCR accuracy. To get excellent identification results, the study emphasizes the significance of properly calibrating the spatial parameters. Fine-tuning the system for various distance ranges can contribute to greater text extraction and reliability, particularly in real-world circumstances where the ESP32CAM placement may fluctuate. Furthermore, this study emphasizes the need to strike a balance between distance optimization and practical issues such as intended use case and environmental restrictions. The findings lay the groundwork for fine-tuning OCR setups with ESP32CAM in applications, leading to the continuous evolution of efficient and adaptive optical character recognition systems.

Acknowledgement

The author would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussien Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the completing of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

References

[1] Vlad Fernoaga, George-Alex Stelea, A. Bălan, and F. Sandu, "OCR-based Solution for The Integration of Legacy And-Or Non-Electric Counters in Cloud Smart Grids," OCR-based Solution for The Integration of Legacy And-Or Non-Electric Counters in Cloud Smart Grids, p. 398, Oct. 2018, doi: https://doi.org/10.1109/siitme.2018.8599200.

[2] J. Li and Y. Xu, "Remote Monitoring Systems Based on Embedded Database," Remote Monitoring Systems Based on Embedded Database, pp. 381–384, Oct. 2009, doi: https://doi.org/10.1109/wgec.2009.54.

[3] V. N. Sai Rakesh Kamisetty, B. Sohan Chidvilas, S. Revathy, P. Jeyanthi, V. M. Anu, and L. Mary Gladence, "Digitization of Data from Invoice using OCR," 2022 6th International Conference on Computing Methodologies and Communication (ICCMC), pp. 119–124, Mar. 2022, doi: https://doi.org/10.1109/iccmc53470.2022.9754117.

[4] I. C. Education, "What Is Optical Character Recognition (OCR)?," IBM Blog, Jan. 05, 2022. https://www.ibm.com/blog/optical-character-recognition/

[5] Rungaroon Khunsamitpanya, Rangsiman Yotsongpol, Sharunya Srichanpliuw, and Chanchai Techawatcharapaikul, "The Energy Meter Translation by Optical Character Recognition Technique," pp. 412–415, Mar. 2021, doi: https://doi.org/10.1109/ieecon51072.2021.9440304.