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Automated Water Meter Reading through Image Recognition

M. Madhuri Latha[1], P. Sowmya[2], K. Aruna[3], U. Sathwika[4], K. Tejaswini[5]
[1]Assistant Professor, [2, 3, 4, 5]Student, Electronics and Communication Engineering, G. Narayanamma Institute of Technology and Science, Hyderabad, India

Abstract: In this paper, we propose a solution for reading an analog water meter automatically by digitalizing the meter. Since digital water meters are expensive, we retrofit the meter using Raspberry Pi, a camera, and an LED. Though the structure of the analog water meter is simple, consumes less power, and has high durability, it has some disadvantages. Primarily, it requires human effort for reading, which is time-consuming and causes inconvenience to users. To address this challenge, there is a need for an automated system. Thus, the project is implemented using image recognition techniques, specifically Optical Character Recognition (OCR), and Internet of Things (IoT). This method accurately detects the numerical values present on the meter, and this data is transmitted to ThingSpeak, an IoT platform. Overall, this project offers an effective solution for reading water meters and enhance the comfort and convenience of users.
Keywords: Image Recognition, Optical Character Recognition, IoT, ThingSpeak, Water Meter, Raspberry Pi.

I. INTRODUCTION

As the population continues to increase, conserving and using water precisely becomes crucial, and tracking water usage accurately is important. The volume of water passing through the pipe is measured by a mechanical device called water meter. Water meter displays only readings and it is difficult and error-prone to track water usage. Therefore, digitalization can be done to track water usage for resource management, identify usage patterns and trends over time, and enables users to implement water-saving practices. Before delving further into project, it is important for users to understand how to read a water meter reading. Reading of the meter displayed below is 3286.103KL or 3286103L.


Fig. 1 Analog water meter reading

From the above reading it is clear that manual readings can prone to error. Therefore, the project focuses on developing an automated water meter reading system to overcome the challenges associated with manual readings. By using image processing techniques particularly OCR, we aim to accurately extract meter readings from images of the water meter. Once the readings are extracted, they are transmitted to ThingSpeak, an IoT platform, for further analysis. This data also allows us to monitor daily water consumption patterns.

II. LITERATURE SURVEY

Water Meter Reading can be done in many methods. Many researchers approached different methods to read water meter readings, some of the research papers are considered below:

A. Improving IoT- based Smart Retrofit Model for Analog Water Meters using DL based Algorithm

The paper introduces a deep learning-based algorithm aimed at enhancing digit detection in IoT-based analog water meters. Trained on a diverse dataset of over 160,000 images from six different water nodes, the algorithm demonstrates robustness and generalization capabilities. A comprehensive comparison with traditional machine learning methods underscores the superior performance of the deep learning approach, particularly in complex environments. While acknowledging the importance of dataset diversity, the paper suggests future enhancements, such as "half-digit" detection, opening avenues for further research and development to improve real-world utility.

B. Digitization of Conventional Water Meters using Automated Number Recognition

The paper presents a prototype for water meter number recognition using OCR techniques, featuring a comprehensive design process covering component selection, electronic circuit, PCB, software coding, and shell case design. The ATmega1284p microcontroller was chosen for its suitability, emphasizing simplicity and cost-effectiveness in circuit design. While the prototype effectively digitized conventional water meters, limitations include the microcontroller's processing power and potential for improved recognition accuracy. Real-world application would require speed optimization, enhanced algorithms, and addressing environmental concerns. Further refinement is necessary to enhance practical viability beyond controlled environments.

III.PROPOSED SYSTEM

The proposed system is Automated water meter reading system. This aims to automate the process of reading wat meters using image recognition technology. The system utilizes hardware components such as water meter, Raspberry Pi 3 Model B+, camera, LED and power supply. Additionally, it uses software components like the Raspbian OS and ThingSpeak platform. The block diagram of physical components and interconnection is shown below.

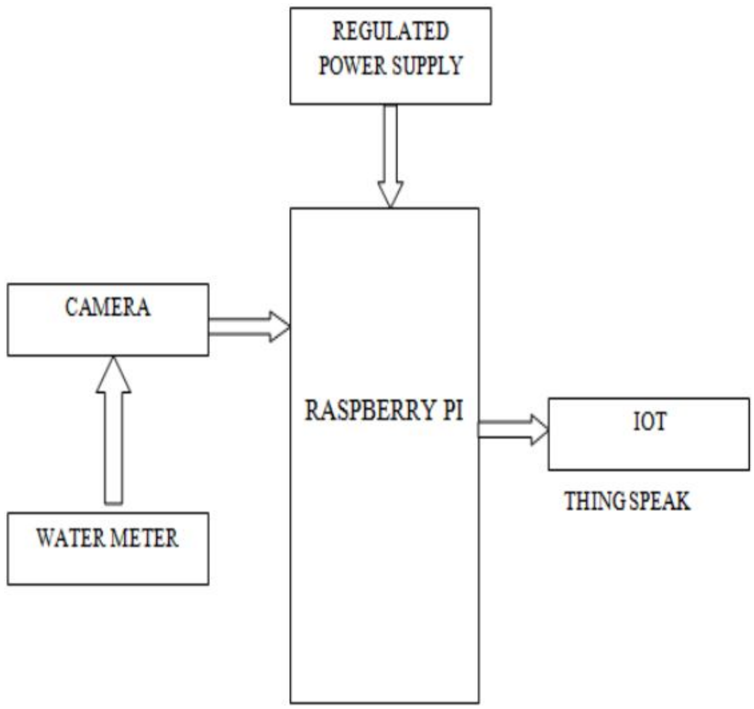

Fig. 2 Block Diagram of Physical Components

A. Raspberry Pi

The Raspberry Pi functions as the central processing unit and the core of the system, serving as its brain. It executes Python scripts responsible for various tasks such as image capture, preprocessing, and digit recognition.

B. Camera Module

Zeb-Crystal Pro, a USB powered web camera with built-in microphone and LED is used. Using camera frames can be captured and enables users to retrieve images from the camera feed and save them for further analysis.

C. Water Meter

Water meter itself serves as the physical source of data. Positioned within the system's view, the water meter is the focal point for image capture by the camera module. The system's primary function is to capture images of the water meter using the camera connected to the Raspberry Pi. These images are then processed using image recognition techniques implemented in the Raspbian OS. The system employs python scripts to extract the meter reading from the captured images. The system uploads extracted data to the ThingSpeak platform.

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IV. WORKFLOW OF THE SYSTEM

The workflow of the system comprises three main steps: Image Capture and Storage, Image Recognition and Digit Recognition, and Uploading to ThingSpeak. The flowchart provided below illustrates how system operates.

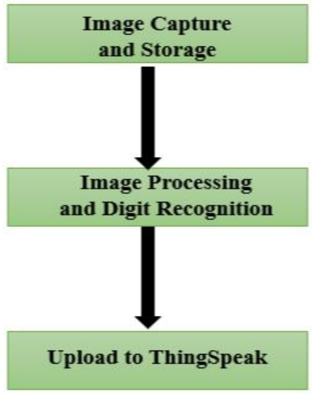

Fig. 3 Workflow of the System

A. Image Capture and Storage

Capturing frames of the water meter using a camera connected to the Raspberry Pi and saving these frames for further processing is a primary step.

1) *Image Capture*: This step involves capturing frames of the water meter using a camera connected to the Raspberry Pi.
2) *Frame Storage*: Once frames are captured, they are stored for further processing. The frames are typically saved as image files in a suitable format, such as JPEG, on the Raspberry Pi's storage device.

B. Image Capture and Storage

This part of the system involves processing the captured images to extract digits representing the water meter readings and then recognizing these digits using OCR technique.

1) *Image Reading*: Image reading involves loading an image file using the OpenCV library. The loaded image is stored in the variable 'image' and will serve as the input for subsequent processing steps.
2) *Preprocessing*: Convert the image to grayscale and apply binary inversion using thresholding. The original colour image is converted to grayscale. The grayscale image is then threshold using Otsu's method. This technique automatically determines an optimal threshold for binary segmentation, enhancing the contrast between the digits and the background.
3) *Digit Extraction*: The binary image obtained after thresholding is used to find contours. Images are the bounded contour . Locate contours within the binary image. Each contour representing a digit is extracted from the image.
4) *Digit Recognition*: For each contour, the ROI is extracted from the threshold image. Tesseract OCR is applied to recognize text within the ROI and recognizes the digits extracted from the image.
5) *Display Reading*: The recognized digit is printed to the console. This step provides immediate feedback on the digit detected in the image

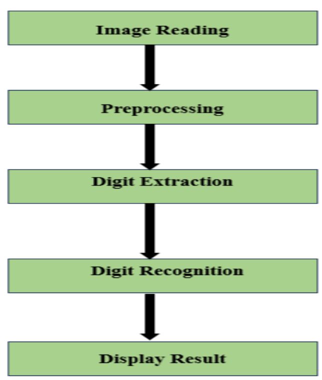

Fig. 4 Image Processing

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C. Upload to ThingSpeak

This part of the system handles the process of uploading the recognized water meter readings to the ThingSpeak platform for storage or further analysis.

1) *Upload Function*: The system defines a function named upload that takes the recognized digit (reading value) as a parameter.
2) *HTTP Request*: Within the upload function, an HTTP request is sent to the ThingSpeak API endpoint, including the recognized digit as a query parameter.
3) *Error Handling*: The function handles potential errors during the upload process and prints appropriate messages indicating whether the upload was successful or not

This detailed elaboration demonstrates how each step in the workflow contributes to the overall process of digit detection using image processing and Tesseract OCR. The combination of image preprocessing, contour detection, and OCR techniques allows for the extraction and recognition of the digits from the input image and the process of uploading the data to ThingSpeak.

V. RESULTS

Automated water meter reading system has been successfully implemented. The implemented automated water meter reading system comprises interconnected hardware components as shown in the below figure.

Fig. 5 Automated Water Meter Reading System

From the real time video stream captured by a camera focused on the water meter. The camera continuously records the meter's readings, and this video feed serves as the input to the digit detection system. From the live video feed, individual frames are captured at regular intervals or as required. These frames contain images of the water meter at different times, showing the changing meter readings. Each captured frame from the live video feed serves as an input image for the digit detection system. These images contain the visual representation of the water meter, including the digits displaying the meter readings. The input image is shown below.

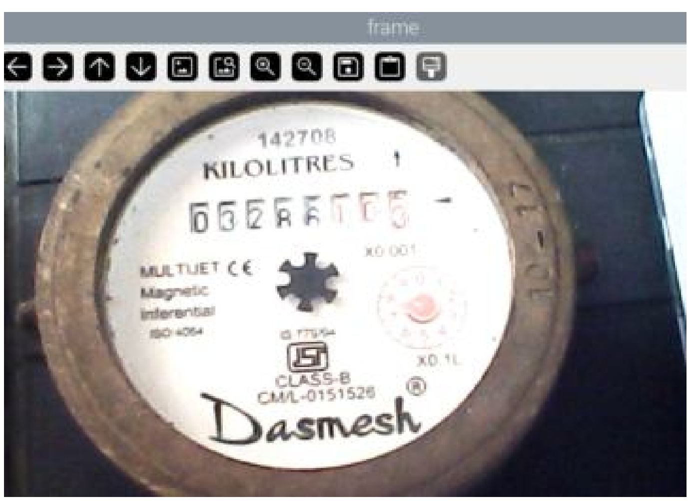

Fig. 6 Input Image

The captured images, containing the readings of the water meters or the data of the water meter reading or volume of the water consumed is stored as shown in the below Fig. 7 and this can be accessed whenever readings need to be detected.

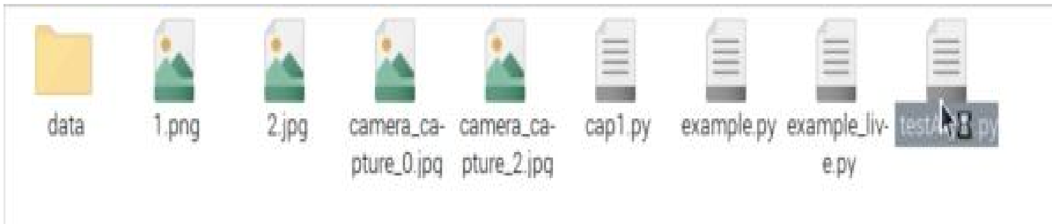

Fig. 7 Captured Images

Finally using the image processing techniques, the digits stored in the form of input image are extracted. These detected readings are then displayed as output on the IDLE shell. After detecting the digits these digits are uploaded to the ThingSpeak IoT platform and the output is shown below.

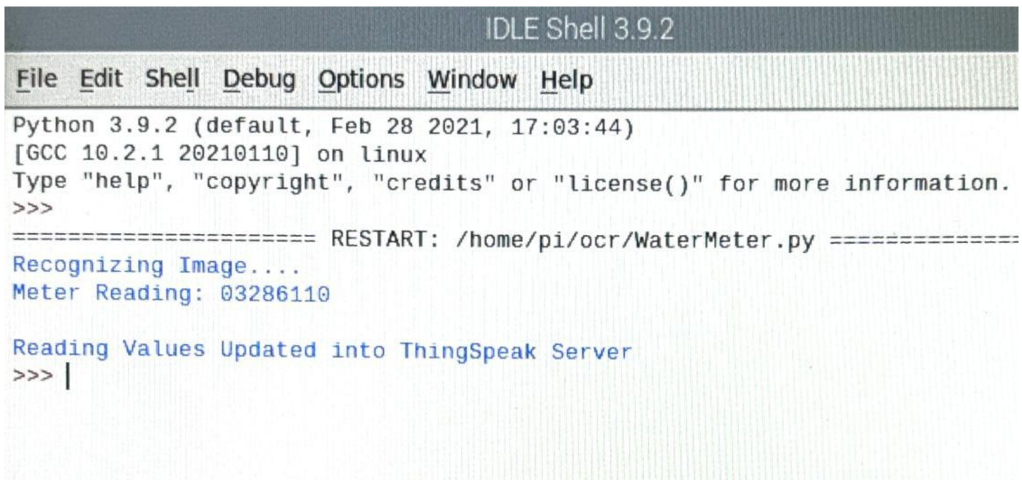

Fig. 8 Detected Digits

Upon recognizing the readings, they are promptly transmitted to ThingSpeak, facilitating direct and universal access for users at any time and from anywhere. The data is organized chronologically, detailing the date and corresponding meter readings. This arrangement enables users to track water consumption patterns and compute usage trends effectively using the below chart. Such accessibility and organization significantly enhance the system's utility, empowering users with actionable insights into their water consumption habits.

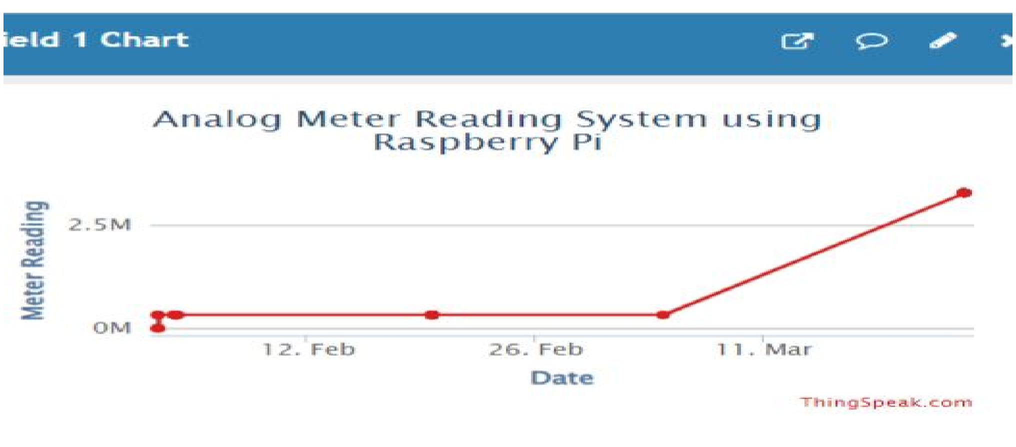

Fig. 9 Water Meter Readings Over Time

VI. CONCLUSIONS

The project introduces an automated system to tackle the challenges of manual water meter reading. By combining a water meter, LED, Raspberry Pi, and Camera, and utilizing image recognition, particularly Optical Character Recognition (OCR) using Python, the system enables real-time transmission of meter readings. This approach eliminates the need for manual recording and significantly reduces errors. Leveraging cost-effective hardware components like the Raspberry Pi and a camera, our system successfully automates the meter reading process, improves accuracy, and minimizes the risk of tampering. By capturing and processing images of analog water meters, accurately identifying and reading the digits representing water consumption, and seamlessly integrating with IoT platforms for data collection and analysis, our solution offers a practical and efficient approach to modernizing water meter reading systems. By achieving its objectives of automation, accuracy, tamper resistance, and data analysis, our system provides a sustainable solution for enhancing operational efficiency and addressing the shortcomings of manual meter reading processes.

VII. FUTURE SCOPE

The implemented system successfully achieved its primary goals, there are several avenues for future enhancements. These Include:

1) Implementation of advanced Image Processing algorithms can be used to improve the accuracy of digit recognition during poor lighting conditions or poor image quality.
2) Alerts can be sent in case of unusual patterns or suspected tampering.
3) Integrate the automated meter reading system with existing billing systems used by utility providers. This simplifies the billing process by automatically generating.
4) Global adoption is likely as benefits become evident, especially in water-stressed regions.
5) The integration of deep learning models, such as convolutional neural networks (CNNs), to further enhance the system's ability to accurately detect and interpret digits from water meter images can be done.
6) Implementation of edge computing capabilities to perform image processing and digit recognition directly on the device (e.g., Raspberry Pi), reducing reliance on external servers and enabling faster response times can be done.
7) Incorporation of a feedback mechanism that allows users to report any discrepancies or issues with the automated readings, enabling continuous improvement and refinement of the system can be done

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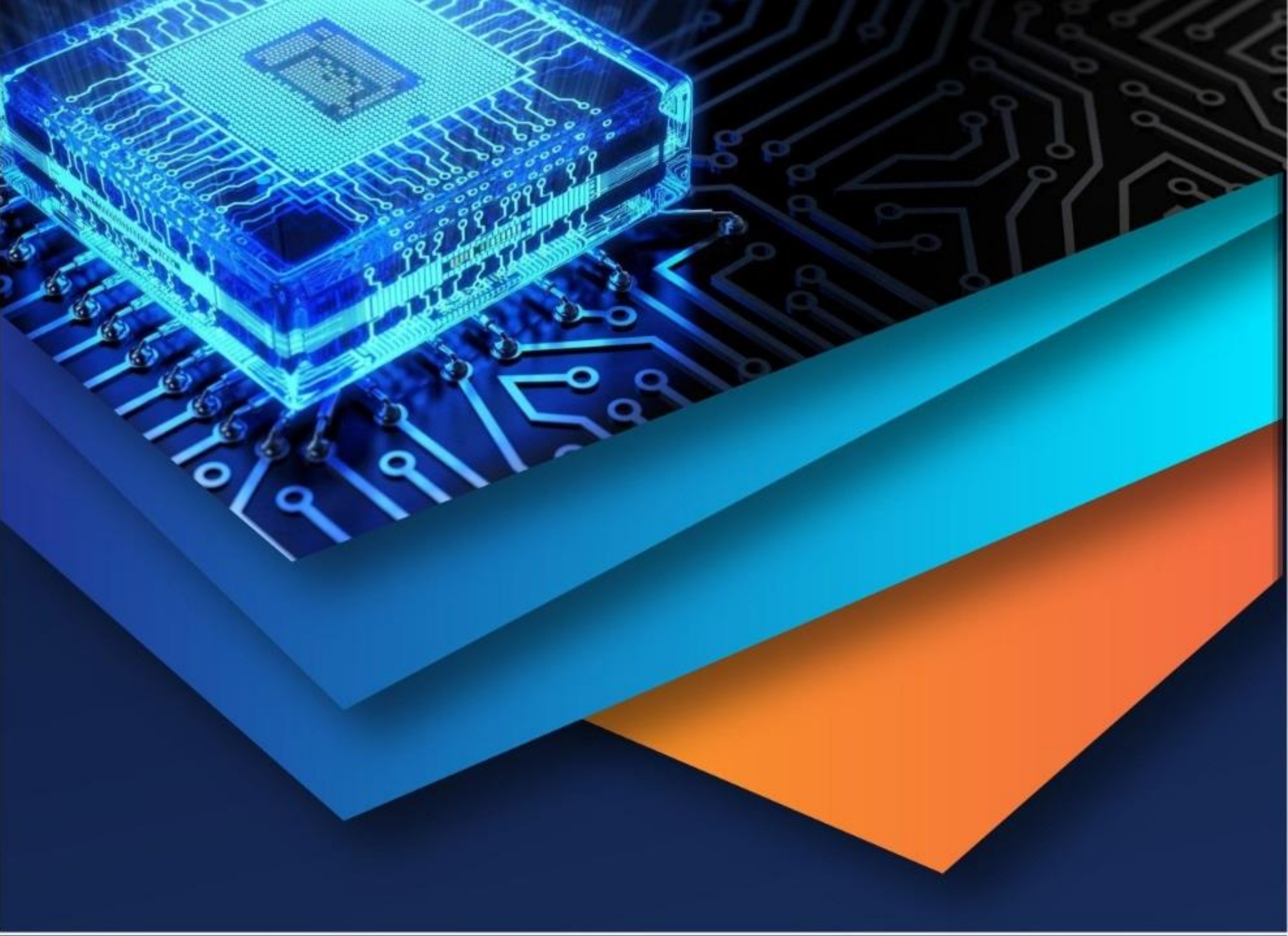

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