Image Processing Based Water Meter Reading System

An Undergraduate CAPSTONE Project
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Faculty of Engineering
American International University - Bangladesh

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A CAPSTONE Project submitted to the Faculty of Engineering, American International University - Bangladesh (AIUB) in partial fulfillment of the requirements for the degree of Bachelor of Science in their mentioned respective programs.

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DECLARATION

This is to certify that this project is our original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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APPROVAL

The CAPSTONE Project titled **Image Processing Based Water Meter Reading System** has been submitted to the following respected members of the Board of Examiners of the Faculty of Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in the respective programs mentioned below on **January 25, 2024** by the following students and has been accepted as satisfactory.

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ABSTRACT

In this era of technology, IoT represents a revolutionary leap in the way we interact with technology and the environment around us. This technology extends connectivity beyond traditional devices. This integration leads to the development of smart water meters that not only automate the reading process but also enhance the capabilities of monitoring, analysis and communication.

This paper introduces a cost-effective image processing system to capture and monitor the analog meter's reading, an innovative solution aimed at modernizing the water meter reading system in Bangladesh. In this project by utilizing OCR the system automatically collects water meter data, thereby enhancing the productivity and precision. The project is centered around the development raspberry pi microcontrollers equipped with Wi-Fi or Sim connectivity and camera modules. This device will capture images from the water meter and then it will perform OCR to accurately extract the water meter consumption. After conducting test, it was determined that it would give more precise results depending on the camera resolution. In this project Pi camera module V2 was used which is 8MP which gave less precise results. But when a better camera was used, which is a lot more efficient than a Pi camera, it gave more accurate results.

The system's strength lies in its advanced automation that significantly reduces the need for manual water meter checks and offers a reliable and time efficient solution for both consumers and providers. So, efficiency can be increased by implementing a camera with better picture quality as lighting conditions don't affect much if the picture quality is good. However, the project faces challenges primarily in image processing. The presence of glass lids on water meters and varying environmental conditions such as insufficient light occurs difficulties in capturing image. Despite its challenges, particularly in image processing the system offers a promising solution.

Chapter 1

INTRODUCTION

1.1. Overture

In the context of Bangladesh, water meter corruption has been a concern due to challenges in the water supply and distribution system. The major consequences of water meter corruption in Bangladesh include water utility losses, income shortfalls, and increased costs for other consumers. According to Prothom Alo (23 February 2022), 20% of the water Dhaka WASA (Water Supply and Sewerage Authority) produces each day does not make it to the customers. 'System loss' is the term used to describe this. While the Dhaka WASA asserts to produce 2.6 billion liters per day, the daily water requirement in Dhaka city is estimated to be 2.5 billion liters. Due to system loss, 520 million liters, or 20%, of the water generated does not reach the customers [1]. To overcome this situation our resources should be used wisely, and regular monitoring has become essential. Collecting water meter data is a crucial step in achieving this objective. In this paper, we propose an Image Processing Based Water Reading System to automate water meter data collection by performing OCR. This technology will provide effective services to water consumers and water providers such as consumption monitoring and detection of water losses from supply. Chong Yue Jiet prepared a project about Development Of Image Recognition System For Analogue Meter's Reading Detection [2]. This paper introduces a cost-effective image recognition system to capture and monitor the analog meter's reading and send the data to the Firebase Real-time Database. The effectiveness of a digital water meter reading system in preventing water meter corruption depends on the system's correct deployment, upkeep, and security measures against hacker attacks and unauthorized access. The main goal of our project is to create an automatic water meter reading system that will replace the analog meter reading system.

1.2. Engineering Problem Statement

The OCR-Based Automatic Water Meter Reading System represents a sophisticated engineering initiative aimed at optimizing the water meter reading process by leveraging the capabilities of Optical Character Recognition (OCR) technology. The OCR-Based Automatic Water Meter Reading System encountered several challenges throughout its development and implementation phases. One significant challenge involves the degradation of image quality due to aged and pre-owned water meters, leading to blurry screens and dust accumulation. Another hurdle was the variation in meter display types, requiring modifications to the OCR coding for accurate reading across different models. Training the OCR model to improve accuracy and addressing errors in printed data were essential tasks. Integrating the OCR system with existing utility management systems and databases posed synchronization challenges, especially concerning data transmission security and network connectivity in areas with limited access. Hardware implementation involved selecting appropriate cameras, LED lights, and lenses for consistent image capture in various environmental conditions, as well as determining suitable battery sizes. Calibration of camera angles and LED adjustments were critical for accurate readings. Integration with utility management software required proper parsing and validation of extracted data to prevent billing errors and maintain data integrity. Optimizing software for real-time data processing and developing an intuitive user interface pose significant technical challenges. The optimization of software for speed and efficiency posed a significant challenge in the context of real-time data processing. The development of an intuitive and user-friendly interface for utility people, technicians, and administrators posed a substantial software challenge.

1.3. Related Research Works

Briefly discuss the research works done related to the focused topic. Provide proper referencing [IEEE format] and indicate how the results / outcome of mentioned research works helps to build the project. Smart water reading systems through OCR have been a topic of research in the field of computer vision and image processing. This system aims to automate the reading of water meters from images, making the process more efficient and reducing the potential for errors. To implement this project, several research papers were gathered and analyzed to acquire knowledge. To get more information about the topic and to get a better understanding of what areas need to be improved many papers were reviewed.

1.3.1. Earlier Research

In their study titled "Image Type Water Meter Character Recognition Based on Embedded DSP," Liu Ying, Han Yan-bin, and Zhang Yu-lin investigate the integration of a DSP processor with an image processing algorithm. Their research focuses on the methodology employed for recognizing characters on water meters [3]. The researchers obtained the water meter image by capturing it using a camera positioned at a fixed angle. They employed a projection approach to identify and interpret the digital images. The compilation of meter images was established upon a digital signal processing (DSP) chip and employed the OTSU algorithm for the purpose of image processing.

The study conducted by Geyong Yao, Hao Zhang, and Qijun Chen titled "A wireless automatic meter reading system based on digital image process and ZigBee-3G" explores an automatic meter reading (AMR) system that utilizes ZigBee, 3G, and digital image processing technology. The AMR system is characterized by its wireless and totally autonomous nature, resulting in the absence of noise pollution on the power network [4]. The utilization of a Zigbee module is employed for the purpose of transmitting an image to either the image processor or the subsequent meter.

In their study titled "Automatic Reading of Electro-mechanical Utility Meters," Ocampo-Vega, Sanchez-Ante, Falcón-Morales, and Sossa employ a smartphone-acquired image and a series of image processing functions to identify and extract the dial images from electro-mechanical utility meters [5].

The study titled "Study of the Automatic Reading of Watt Meter Based on Image Processing Technology" conducted by Shu, S. Ma, and C. Jing outlined an innovative concept for an automated watt meter reading system, wherein a video camera is strategically positioned in front of the watt meter

to capture real-time images of the meter reading. The numerical value displayed on the meter was identified by the utilization of picture segmentation and character recognition techniques, enabling real-time reading with a high level of efficiency and minimal errors [6].

The study "Research on the Pre-processing Method of Automatic Reading Water Meter System" was conducted by Zhang & Li where they introduced a new algorithm of print wheel region and pointers location based on Fourier transform [7]. Their algorithm could locate the print wheel region and pointers accurately with little computation and shortened the automatic reading system's running time effectively.

The article titled "Automatic Reading of Electro-mechanical Utility Meters" conducted by Ocampo-Vega et al. proposed a method based on image processing and segmentation that enables the image acquisition and processing of pointer dials to obtain readings that are both efficient and accurate [8]. Their method was able to extract the reading in an average of 3 seconds, with 92% accuracy with images taken in-field.

Mudumbe and Abu-Mahfouz's study "Smart Water Meter System for User-Centric Consumption Measurement" introduces the water management system based on wireless sensor networks (WSN). The system is robust and intelligent thanks to the IEEE 802.15.4 standard embedded in ContikiOS LibCoAP as an open-source application [9]. Following the creation of a web-based system and the implementation of Pandora FMS, system visualization and monitoring were accomplished.

1.3.2. **Recent Research**

In their study titled "Retrofitting analogue meters with smart devices," Nohre and Landré (year) demonstrated the application of LORA technology for the purpose of data transfer [10]. The authors put out a proposition for OCR. One potential approach involves the implementation of a battery-operated supplementary device capable of optically scanning meter values through the utilization of Optical Character Recognition (OCR) technology. This device would thereafter send the captured readings via wireless means. There were two potential approaches to accomplish this task: one is to delegate the OCR (optical character recognition) process to a remote server, while the other is to perform the OCR processing directly on the add-on component.

The research article titled "Lightweight AI Framework for Industry 4.0: A Case Study on Water Meter Recognition" by Jalel Ktari, Tarek Frikha, Monia Hamdi, Hela Elmannai, and Habib Hmam presents a novel methodology for monitoring and tracking water consumption through the utilization of Optical Character Recognition (OCR) technology, coupled with an artificial intelligence algorithm, specifically the YoLo 4 machine learning model. The objective of this study was to deliver optimized outcomes in real time. The algorithms developed in this study achieved a recognition rate of approximately 98%. [11].

The authors of the study titled "Measurement of Water Consumption based on Image Processing," namely Ondrej Kainz, Matus Dujava, and Rastislav Petija, presented a method for the automatic visual collecting of water consumption data and the subsequent processing of this data to identify non-standard situations. The practical application of the proposed theoretical approach involved the integration of a sophisticated system comprising a server component and a client component. The client component conducted periodic measurements from the water meter. The data was recorded in the database by the server, and it utilizes human input to identify and address nonstandard conditions that may arise during real-time measurement. The complete system underwent testing within an authentic environment. The solution successfully identified simulated water leaking. The proposed method offers the user a comprehensive overview of the total water consumption inside a household [12].

In their research article titled "Water meter pointer reading recognition method based on target-key point detection," Zhang et al. discussed a model for detecting target-key points. The model was separated into two sub-modules: a target detection module and a key point detection module to address the shortcomings of the traditional detection model [13]. The objective of the target detection module was to identify and locate the dial region and the pointer area. The objective of the key point detection task was to execute key point detection on the given pointer image. accordingly, readings were conducted in accordance with the outcomes obtained from the key point detection analysis.

In the article titled "A fully AI-based system to automate water meter data collection in Morocco country" In this study, Naim et al. provide a comprehensive artificial intelligence (AI) system designed to automate the process of collecting water meter data. The system consisted of two main components: a Recognition System (RS) and a web services platform [14]. The Recognition System utilized an embedded system incorporating a Convolutional Neural Network, which was trained on our proposed MR-AMR dataset. Additionally, a web services platform was implemented, offering various services including consumption monitoring, water leak detection, visualization of water consumption on a geographic map, reporting services, and assessment of potable water coverage.

In their research titled "Analogue meters in a digital world: Minimizing data size when offloading OCR processes" Davidsson and Sjölander demonstrated the potential of reducing power dissipation from the battery by offloading the OCR process. Furthermore, they found that this dissipation can be further minimized by reducing the quantity of transmitted data [15]. A total of 250 analog water meter value photos were subjected to processing using the Google Vision Cloud OCR. This involved testing 38,000 unique combinations of resolution, color depth, and upscaling techniques. The study illustrated the possibility of reducing data sizes and thereby reducing energy usage by offloading the OCR process through the transmission of images with small file sizes.

The article entitled "A Deployment Framework for Internet of Water Meters Using Computer Vision on ARM Platform" by Santiago and Alvares introduces an approach primarily implemented in Python. This approach aims to automate the reading procedure of water meters featuring an analog display by leveraging computer vision techniques and machine learning algorithms [16]. They used the SVM machine learning model and executed the software over an ARM platform.

The article titled "Development of image recognition system for analogue meter's reading detection" by CHONG YUE JIET presents a cost-effective image recognition system that utilizes a deep learning model (specifically, SSD MobileNet) and optical character recognition (OCR) using Tesseract. The system aims to capture and digitize the readings of analog meters [17]. The findings of the study revealed that the deep learning model achieved an accuracy of 95%, while the OCR system demonstrated an accuracy of 91%.

The article “Water Meter Reading for Smart Grid Monitoring” by Martinelli et al. proposed a method intended to localize the dial meter from an image, detect the digits, and classify the digits. The utilization of deep learning techniques was employed in the investigation, with particular attention given to the YOLOv5s model, for the purpose of localizing digits and then recognizing them [18]. The primary issue that was discovered pertained to the confusion arising from specific numerical digits.

Ye et al. proposed a LoRa-based low-power smart water meter system, which is called SWATS (Smart Water Metering System) [19] in their study titled "A LoRa-based Low-power Smart Water Metering System". The SWATS system employs a sensor and a microprocessor to evaluate the condition of the water meter, subsequently computing the real-time water consumption volume. In the context of data transmission, SWATS and its server establish communication with minimal power consumption by utilizing LoRa technology. LoRa is characterized by its ability to facilitate secure data transmission over long distances while consuming low levels of power.

1.4. Critical Engineering Specialist Knowledge

To develop the project several critical engineering specialist knowledge areas successfully and effectively are required. Due to the project's use of several disciplines and technologies, these fields cover a broad spectrum of competence.

1.4.1. **Computer Vision and Image Processing:** It's essential to have a solid grasp of image processing and computer vision methods. Understanding of edge detection, object identification, picture segmentation, and feature extraction are included in this.

1.4.2. **Machine Learning and Deep Learning:** Experts should be knowledgeable in both machine learning and deep learning methodologies in order to develop models for precise water meter readings. Understanding optical character recognition (OCR), neural networks, convolutional neural networks (CNNs), and data labeling for training are all included in this.

1.4.3. **Image Acquisition:** Image acquisition specialists can make sure that the device takes crisp, high-definition pictures of water meters. It is vital to have a working understanding of the hardware, optics, and lighting of cameras.

1.4.4. **Signal Processing:** To preprocess photos to reduce noise, boost contrast, and increase overall image quality, it's crucial to understand the fundamentals of signal processing. Filtering and Fourier analysis are some of the methods used in this.

1.4.5. **Embedded Systems:** To make the image processing system work with the water meters in the real world, experts in embedded systems must provide hardware and firmware.

1.4.6. **Software Development:** Creating programs for image processing, data storage, and user interfaces is part of the project's software component. It is crucial to be proficient in important software libraries, as well as programming languages like Python.

1.4.7. **Database Management:** To manage and store the water meter reading data effectively and securely.

1.4.8. **Internet of Things (IoT):** Integration with IoT devices for remote monitoring and control is required. The networking and communication components of the system are designed by IoT professionals.

1.4.9. **Optical Character Recognition (OCR):** A crucial part of the project, reliable extraction of numeric values from photographs of water meters requires the expertise of OCR experts.

1.4.10. **Security and Privacy:** It's critical to ensure data security and privacy, especially when working with client data. It's necessary to be familiar with cybersecurity, authentication, and encryption.

1.4.11. **Data Analytics and Visualization:** Data analysts may provide insights by processing and presenting the gathered data in a way that can be helpful to both end users and decision-makers. To confirm the correctness, dependability, and performance of the system, testing, and quality assurance specialists should be engaged.

1.4.12. **Maintenance and Support:** To ensure the system's long-term dependability and performance, you must be knowledgeable about continuing system maintenance and support.

1.5. Stakeholders

The project involves stakeholders from many backgrounds and organizations that have a vested interest in its effective execution. The stakeholders considered in this study include the following:

1.5.1 **Government authorities:** Government agencies and regulatory authorities show a strong interest in precise water meter readings to uphold fair billing practices and promote effective resource management. When it comes to water distribution and metering, they are crucial in shaping policy and regulation.

1.5.2 **Water utility companies:** Water utility companies have the primary responsibility of overseeing and facilitating the management and distribution of water resources. The implementation of this system offers advantages by enhancing billing precision and mitigating revenue losses resulting from corruption or mistakes.

1.5.3 **Consumers:** The end-users of the water supply play a crucial role as stakeholders due to their direct reliance on and advantages gained from enhanced meter readings that are clear and precise. The ability to obtain real-time usage statistics enables individuals to engage in water-saving practices and effectively manage their budgets.

1.5.4 **Technology providers:** Manufacturers of the necessary components and providers of the necessary technical competence are also important to the success of this system. The achievement of their goals is reliant upon the effective implementation of their proposed solutions.\

1.5.5 **Technicians and engineers:** The individuals who are accountable for the installation, maintenance, and enhancement of the water meter reading systems are crucial stakeholders. The proficiency of the individuals involved guarantees the dependability and durability of the system.

1.5.6 **Financial Institutions:** The accomplishment of this project may have an impact on the decisions of banks and other financial institutions regarding the provision of loans and other forms of financial support to water utility companies or individual consumers.

1.6. Objectives

The objective of this project is to create a modern water meter reading system that utilizes image processing techniques. This system will be implemented using a Raspberry Pi equipped with integrated Wi-Fi or SIM connectivity and a camera module. The objective of this system is to substitute traditional analog water meters with an external device capable of capturing photographs of the meter readings. The acquired photos will be sent to the Raspberry Pi microcontroller, where optical character recognition (OCR) technology will be utilized to obtain precise meter values. The aim of implementing this solution is to effectively tackle the prevalent problems of corruption and inaccuracy associated with water meter readings in Bangladesh. By adopting this solution, we seek to provide a dependable and automated method for meter reading, hence fostering enhanced accountability and transparency within the water supply system.

1.6.1. **Primary Objectives**

The primary objective of this project is to design and implement a water meter reading system using image processing techniques.

- Develop an image processing-based water meter reading system.
- Utilize Raspberry Pi with Wi-Fi/SIM connectivity and a camera module.
- Automation of meter reading process.
- Reduction of corruption and inaccuracies in water meter readings.
- Enhance transparency and accountability in the water supply system.
- Provide a reliable solution to a critical infrastructure challenge.

1.6.2. **Secondary Objectives**

- Create a user-friendly interface for water utility companies and consumers.
- Enable access to real-time water consumption data.
- Promote efficient water resource management.
- Foster consumer awareness and control over water consumption.

1.7. Organization of Book Chapters

The organization of the book appears to follow a logical and structured flow, with each chapter building upon the previous one. Here's a brief overview of how the contents have been arranged chapter-wise:

Chapter-2: Project Management

This chapter introduces the project, setting the stage for the reader. It covers aspects such as project objectives, scope, timelines, budget, and team structure. The methods and equipment used for project planning and execution are covered in project management discussions. Even though it may not go into specific technical, it's vital for setting the scene and comprehending the general structure of the project.

Chapter-3: Methodology and Modeling

This chapter introduced the specific methodologies used for the development of the project. It may discuss the choice of computer vision, machine learning, and image processing techniques. It introduces the modeling or algorithmic approaches that have been used in the system. It has references to project planning methodologies from Chapter 2 and showcases how those plans are been put into action.

Chapter-4: Implementation of Project

This chapter developed into the technical details of how the project was implemented. The used hardware and software, as well as the incorporation of image processing with water meters, have been discussed. It's the practical realization of the methodologies and models introduced in Chapter 3. The chapter has covered the implementation's difficulties and how they were overcome.

Chapter-5: Results Analysis & Critical Design Review

This chapter included the outcomes of the image processing-based water meter reading system, such as the accuracy of readings, efficiency gains, and any issues encountered during real-world usage. The "Critical Design Review" indicates a comprehensive evaluation of the system's design, possibly covering both technical and project management aspects. This chapter reflected on the project management chapter and how the project's objectives were met or not met based on the results.

Chapter-6: Conclusion

The final chapter typically wraps up the book by summarizing key findings, insights, and lessons learned throughout the project. A high-level analysis of the project's accomplishments, the applications of the findings, and possible areas for more study or development. By going over the project's goals again and reflecting on how they were realized via project management, methodology, execution, and outcomes analysis, it links back to the preceding chapters.

Chapter 2

PROJECT MANAGEMENT

2.1. Introduction

The water meter system project using image processing was carefully planned and managed, following basic engineering management principles. The initial phase involved a comprehensive project scope definition, identifying key objectives, constraints and stakeholder requirements. A detailed project plan was then executed. The management system of the project will be briefly analyzed in this chapter. The project was strategically managed, balancing technical requirements with effective team collaboration.

2.2. S.W.O.T. Analysis

S.W.O.T analysis is a strategic planning technique used to determine and evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project. Figure 2.1 represents the S.W.O.T analysis of the project.

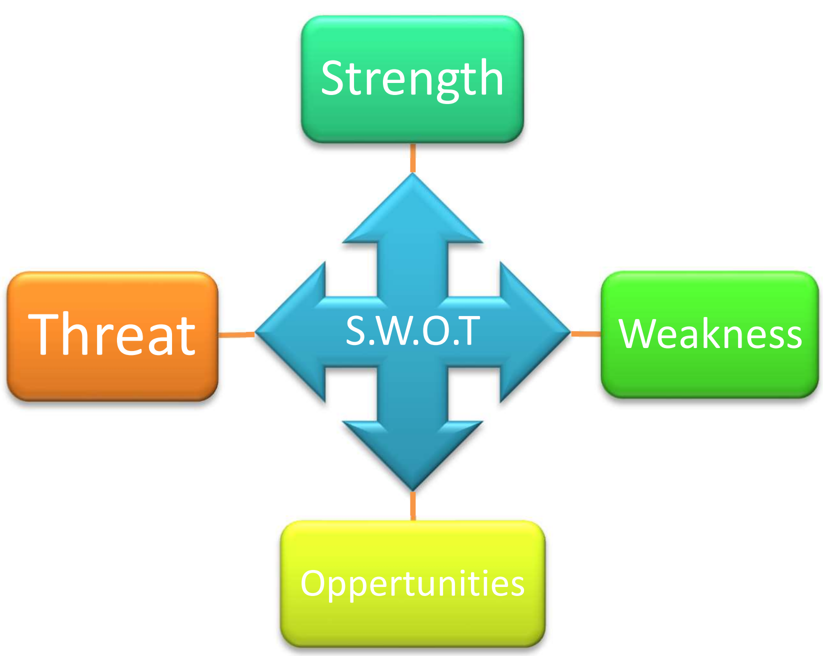


Figure 2.1 S.W.O. T Block Diagram

2.2.1 Strength:

The significant strength of this project lies in its advanced automation, allowing the system to be remotely controlled from any location across the country through the Internet. This capability empowers both consumers and providers to effortlessly monitor the meter's status and performance from any part of the world. The elimination of the need for manual meter checks is a noteworthy advantage for providers, as they can efficiently handle billing tasks directly from their offices. Through a single command executed on the website or app, providers can instantly access the meter rate, ensuring a streamlined and time-efficient process. Moreover, the system provides an added layer of authenticity verification for the meter rate through the website or app. Every command triggers the module to capture an image of the meter and utilize Optical Character Recognition (OCR) to extract the reading. Simultaneously, the raw image is securely stored in the local storage, creating a comprehensive record of each reading. This feature offers an invaluable reassurance mechanism – in case of doubts or errors in the reading, the raw picture can be referenced for verification. In essence, the project's greatest strength lies in the automation of the water meter reading system, enhancing efficiency, reducing manual efforts, and providing a reliable mechanism for accurate monitoring and verification.

2.2.2 Weakness:

Despite its notable strengths, this project is not without its weaknesses. The primary challenge lies in the domain of image processing, which represents the project's most significant vulnerability. The use of image processing encounters difficulties due to the presence of glass lids on water meters, contributing to compromised picture quality and subsequently, suboptimal Optical Character Recognition (OCR) results. The glass lids introduce reflections that significantly hamper the clarity of the images captured, posing a hurdle to the accurate extraction of meter readings. Another weakness stems from the environmental conditions surrounding water meters. Typically positioned in areas with insufficient light, the project employs LEDs in conjunction with the camera to address this limitation. However, the use of LEDs introduces a new challenge: the reflected light on the glass lid diminishes the overall picture quality. Efforts were made to mitigate this issue by exploring different LED positions, ultimately determining the most effective placement. Furthermore, the OCR process itself, reliant on machine learning techniques, introduces a level of inherent inaccuracy. Despite continuous optimization, achieving a 100% accuracy rate remains elusive, and occasional inaccuracies may be observed in the OCR results. In summary, the primary weakness of this project lies in the challenges associated with image processing, particularly the impact of glass lids on water meters, difficulties related to ambient lighting, and the inherent limitations of the OCR process, which collectively contribute to occasional inaccuracies in meter readings.

2.2.3 Opportunities:

The project unfolds numerous opportunities, particularly in the context of the prevailing manual water meter reading system in Bangladesh. Introducing an automated water meter reading system presents a substantial opportunity for advancement in the domain of the Bangladesh Water Development Board (BWDB). This innovation provides an efficient and modern alternative to the traditional manual methods, ushering in a new era of streamlined operations and improved management of water resources. One of the significant opportunities arises in collaboration with the Water and Sewerage Authority (WASA). The project enables WASA to transcend the limitations of manual meter reading, offering a more sophisticated and time-effective solution. Importantly, this system is designed to be compatible with existing, older meters, sparing consumers the need to replace their meters with newer models. This compatibility ensures a seamless transition to automation, allowing consumers to benefit from the advantages of digitalized meter readings without the inconvenience of meter replacements. Moreover, before the complete transition to digital water meters, WASA can leverage this project to gradually digitalize the existing pool of traditional meters. This phased approach allows for a cost-effective and efficient upgrade, providing a bridge between the current manual system and a fully digitalized future. The project, therefore, not only addresses the immediate need for automation but also presents a strategic opportunity for a gradual and smooth transition to a more advanced water meter infrastructure.

2.2.4 Threats:

While the project presents several positive aspects, it is crucial to acknowledge and address potential threats. The most significant threat to this project is cost. The utilization of Raspberry Pi and Pi Camera components inherently contributes to the project's overall expense. Despite efforts to optimize efficiency and functionality, the cost reduction potential remains limited. This financial challenge may impact the project's feasibility and acceptance, particularly in environments with budgetary constraints. A notable threat emerges from the dynamic market conditions. If a digital water meter is introduced to the market at a lower cost than the current project, it poses a considerable risk. Consumers may find it more appealing to invest in newer and more cost-effective digital meters rather than opting for the project's retrofitting solution. The emergence of affordable alternatives could significantly impede the project's adoption and success. To mitigate this threat, future upgrades to the project should be considered. One potential solution involves shifting the Optical Character Recognition (OCR) process to the cloud. While this could reduce reliance on the Raspberry Pi, substituting it with a comparatively cheaper microcontroller, the implementation of OCR in the cloud introduces its own complexities. This approach necessitates a comprehensive study to ensure seamless integration, reliability, and data security. Managing this transition effectively will be essential to counter the threat posed by cost and market competition, allowing the project to remain competitive and economically viable.

2.3 Schedule Management

Creating a project schedule is an important aspect of project management. Schedule management if the process of defining project task and their duration, dependencies and assigned resources in order to complete the project within a designated timeframe. It also includes monitoring and reporting on the schedule to ensure the project is delivered on time. In this project, the project schedule will be highlighted with the help of Gantt chart. In Gantt chart all the individual tasks and performances were focused and enlightened with a particular time range. Figure 2.2 represents the whole procedure we have been through this whole-time step by step.

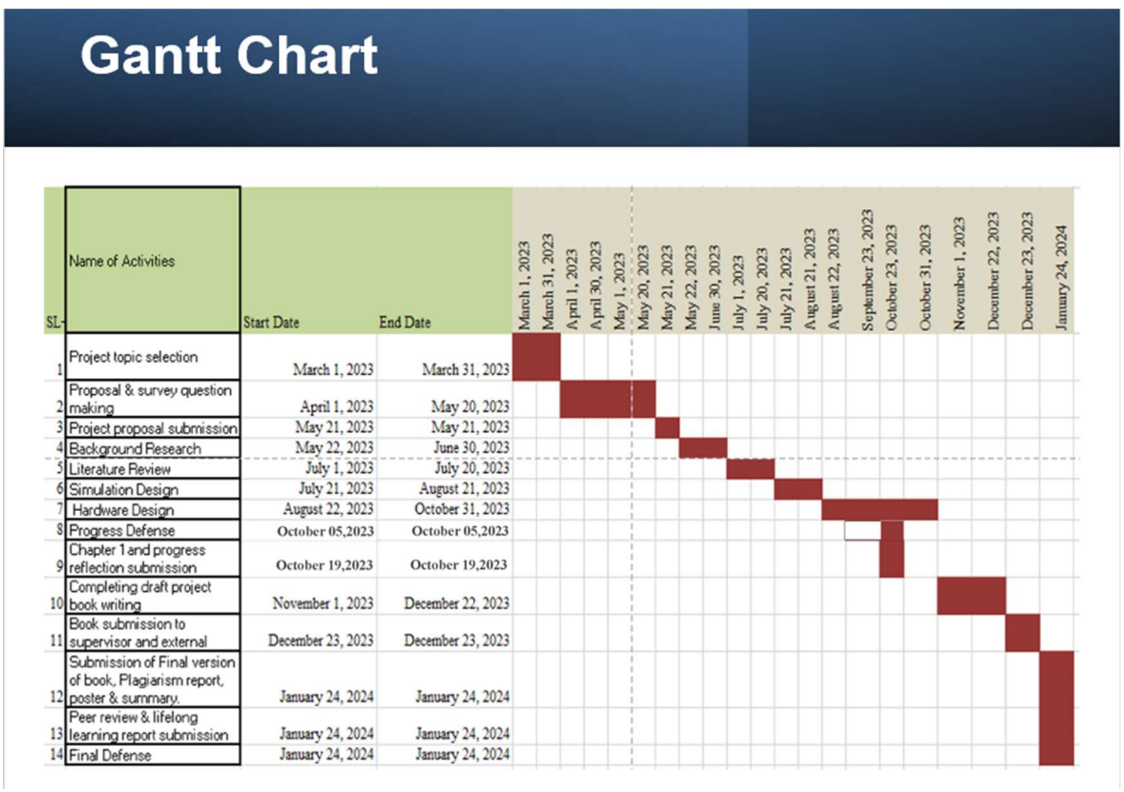


Figure 2.2 Gantt Chart for Schedule Management

2.4 Cost Analysis

Cost Analysis in a crucial aspect of project management and it holds significant importance in this project. Cost analysis helps in allocating the resources efficiently to ensure that the project objectives are met within the constraints. Every small component, even the travel cost that was spent to buy components are included for cost analysis. Table 2.1 provides an overview of the potential cost analysis for the project.

Table 2.1 Cost analysis

Serial	Equipment Name	Quantity	Expected Price (BDT) χ	Market Price (BDT) $\bar{\chi}$	$\chi - \bar{\chi}$	$(\chi - \bar{\chi})^2$
1	Raspberry Pi 3B+	1	12500	11000	1500	2250000
2	Pi camera module V2	1	5000	4690	310	96100
3	2-Channel Relay Module	1	200	200	0	0
4	Pi Adapter	1	350	525	-175	30625
5	LEDs	10	50	15	35	1225
6	3d Modeled Case	1	1000	1500	-500	250000
8	Heat Sink	1	50	50	0	0
9	MicroSD Card	1	250	250	0	0
10	MicroSD Card Reader	1	300	300	0	0
11	LAN Cable	1	250	390	-140	19600
	Total	…….	……	……	……	2647550

The Standard Deviation Formula, SD= $\sqrt{\frac{\sum(\chi-\bar{\chi})^2}{n-1}} = \sqrt{\frac{2647550}{11-1}} = TK. 514.543$

2.5 P.E.S.T. Analysis

Figure 2.3 shows the block diagram for the P.E.S.T analysis.

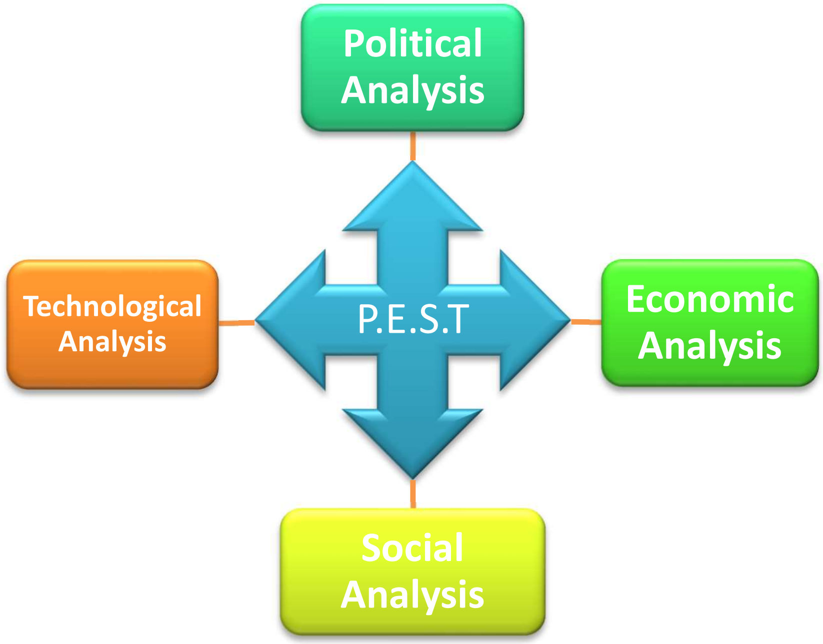


Figure 2.3 P.E.S.T Block Diagram

2.5.1 Political Analysis:

- **Environment of Regulation:** Regulations of data privacy, water utilities, and technological use govern how our initiative operates. Maintaining adherence to these standards is crucial for facilitating smooth operations and fostering public confidence.
- **Support from Government:** The project aligns with government programs that support water conservation and innovative city initiatives. Official support may make funding and legitimization easier.
- **Modifications to Policy:** Future policy changes relating to technology and water management may impact our initiative. It will be easier to modify our strategy to stay current and compliant if we keep track of any potential regulatory changes.

2.5.2 Economic Analysis:

- **Cost Efficiency:** By substantially reducing the expenses related to human meter readings, the system provides utility companies with a more effective and affordable alternative.
- **Demand in the Market:** There is a growing need for automated water meter reading devices. The primary goal of our investigation is to pinpoint the markets and geographical areas that benefit most from our approach.

- **Opportunities for Funding:** We investigate a range of financial options, such as grants from the government, venture capital, and strategic alliances, to facilitate the growth and expansion of our initiative.

2.5.3 Social Analysis:

- **Public Acceptance:** It is important to comprehend how society views utility automation and digital monitoring. As part of our plan, we will inform the public about the advantages and security features of our system.
- **Impact on the Workplace:** The switch to automated meter reading may impact the professions of traditional meter reading. We intend to examine and respond to these developments, maybe recommending retraining courses for impacted employees.
- **Environment:** The growing concern about environmental conservation and its ability to increase water efficiency may impact the adoption of our concept.

2.5.4 Technological Analysis:

- **Technological Advancements:** The success of our system is mainly dependent on ongoing developments in image processing, O.C.R., and IoT. We continuously evaluate new technologies that have the potential to improve system performance. The actual application of our technology needs an assessment of its compatibility and integration with existing water meter technologies and utility databases.

- **Privacy and Data Security:** Responsibly managing customer data is a primary concern. Robust security features are included in our system to preserve data privacy and adhere to legal requirements.

2.6 Professional Responsibilities

The current era of Internet of Things (IoT) devices is distinguished by a significant advancement in intelligence, connection, and integration across several industries. These gadgets, which are integrated with sensors, actuators, and networking capabilities, are revolutionizing whole sectors, and playing a bigger role

in our everyday lives. IoT devices can now analyze data locally thanks to developments in edge computing, which lowers latency and enhances real-time decision-making. IoT devices that have machine learning algorithms embedded into them are more intelligent and adaptable due to their improved capacity for data analysis and response. During a project, engineers have a lot of obligations when it comes to IoT systems.

In this project our primary responsibility is to design and construct reliable automated systems that can measure, and record water use with accuracy. To provide accurate and trustworthy readings, this entails developing complex algorithms for image processing or sensor data interpretation. The responsibility of

effortlessly integrating these systems into the current water infrastructure falls to engineers, who must take compatibility with various meter types and scalability into account. Thorough testing is necessary to confirm the system's correctness in a range of environmental circumstances and ensure its usefulness in practical situations. An engineer's job obligations are diverse and include a variety of technical, ethical, and teamwork-oriented tasks. The responsibility of using their knowledge to create, develop, and execute creative solutions to difficult problems falls on engineers. Their dedication to maintaining safety regulations, environmental concerns, and societal welfare is essential to their work. It is required of engineers to follow moral principles to protect the integrity of their work and foster public confidence. To be on the cutting edge of technology, they need to keep up with the most recent developments in their industry and update their expertise on a regular basis. Collaboration across disciplines and effective communication with team members, stakeholders, and customers are critical. The engineering profession can only survive and flourish if information is shared and documented, and if colleagues and aspiring engineers are mentored. Essentially, an engineer's professional obligations go beyond technical proficiency to include moral behavior, clear communication, and a dedication to improving society via their work.

2.6.1 Norms of Engineering Practice

Various research papers and government articles were consulted to gather engineering recommendations and insights for ongoing projects, particularly those focused on implementing an automated water meter reading system. These sources provided a framework of guidelines that were maintained during the project. Here is a list of guidelines that were followed.

1. The design of our project is practical and appropriate.
2. Evaluate and propose effective strategies related to institution, finance and technology for planning and implementing product management in Bangladesh.
3. Provide technical help and coordinate with project officials and consultants.
4. Assist with technical elements of investment projects including electrical engineering.

5. Aligns with SDG 11 and SDG 12 which is to enhance efficient water management and promote sustainable systems.
6. Ensures fair meter readings, preventing corruption and addressing infrastructure issues.
7. Preserves existing meters making the project cost efficient.
8. Ensures transparency of data for both consumer and provider.

2.6.2 Individual Responsibilities and Function as Effective Team Member

The project was completed by the four members with the guidance of our supervisor. We all worked together and were responsible for the successful completion of the project. in our collaborative endeavor to develop an automated water meter system, each team member shouldered distinct responsibilities crucial to the project's success. For successfully completing the project each member participated in different areas.

Table 2.2 shows each member's name with their assigned responsibilities.

Table 2.2 Individual Responsibilities and Functions

Name of the members	**Responsibilities**
Rajit Palit Atri	Preparing progress report
	Book writing (Chapter 1,2)
	Preparing poster
	Preparing all the survey questions
	Software and hardware implementation of the project
Md Inteshar Ishrak	Book writing (Chapter 2,3)
	Rearranging the book
	Collecting the information about cost of all equipment
	Preparing schedule management
	Software and hardware implementation of the project
	Collecting theoretical Information
	Book writing (Chapter 5, 6)
	Preparing PowerPoint slide for Pre-Defense & Final-Defense

Rajia Sultana	Analyzing the result
	Simulation of the project
	Software and hardware implementation of the project
	Preparing summary report
Liza Akhter	Book writing (Chapter 4)
	Preparing all the references
	IoT & physical implementation of the project

2.7 Management Principles and Economic Models

2.7.1 Management Principles

So far, we have endeavored to adhere to and execute the guidance provided by our esteemed supervisor and external supervisor, sir. This process is how we manage the tasks included in the project and maintain the deadline. We use a dedicated folder on our PC to house all the project's documentation.

- **Maintain a to-do list:** Similar to a project Gantt chart, we adhered to a to-do list after the pre defense in order to appropriately manage all deadlines and meet our project's objectives as well as OBE criteria.
- **Planning:** A successful project requires careful planning. We established specific goals, such improving water meter reading accuracy and minimizing manual labour. Timelines, resource allocation, and important milestones were all laid out in our project plan. A thorough risk management plan was created in order to foresee and reduce any obstacles.
- **Proper Background Research:** Acquire further articles from Google Scholar, IEEE Xplore, and Elsevier, and endeavor to comprehend and evaluate the study findings and analysis. We feel that the quantity of material reviewed in the previous and current research part is insufficient, even though we have read almost thirty articles and written more than twenty.

- **Explore Theoretical Concepts:** We learned from several research papers that part of the information we have is entirely theoretical. We also realized that, in order to prepare for simulation, we must create a theoretical model for our project, which is something we are now working on in accordance with the suggestions.

- **Software Used:** For the purpose of programming this project, we used VSstudio software and PYTHON-3 to locate all the most recent Python features and components related to machine learning and deep learning.

- **Video Tutorial:** We observe and attempt to comprehend Python for ML and Deep Learning features via webpages and YouTube lessons.

- **Using the trial-and-error method:** We simply adjust the values of various parameters, verify the spelling, and execute the code if any part of it does not provide the desired results. We repeat this procedure again until we have an output that meets our needs.

- **Utilizing Appropriate Instruments for Formal Writing:** We make use of Grammarly and Quill Bot, seeking assistance with any grammatical errors.

- **Continuous Improvement and Innovation:** We promoted an innovative culture inside our workforce. Our project saw constant improvements and innovative solutions as a result of this drive. It was crucial to stay current with emerging trends in pertinent technology and procedures to guarantee the continuous improvement of our system.

In addition, in order to meet the OBE standards, we make use of additional tools to edit our writing, block diagrams, tables, references, and other elements of professional scientific book writing. To do this, we keep up a project management principles. Figure 2.4 is the management block diagram.

Figure 2.4 Management Block Diagram

2.7.2 Economic models

- **Cost-Benefit Analysis (CBA):** Utilizing Cost-Benefit Analysis, we evaluated the anticipated benefits of the project in relation to its expenditure. This approach assisted in demonstrating the value of the original technological investment, especially in OCR and image processing. The advantages that were measured were lower labor costs as a result of automation, improved billing accuracy, and long-term cost reductions for power firms.
- **Return on Investment (ROI):** In assessing the financial feasibility of our endeavor, the Return-on-Investment model played a crucial role. We illustrated the project's ability to provide long-term financial returns by calculating the ROI, taking into account both direct and indirect advantages. Getting money and support from stakeholders was made possible in large part by this methodology.
- **Scalability and Growth Models:** Additionally, we concentrated on models that enabled expansion and scalability. This was a crucial factor to take into account while planning future growth, including market reach and technological advancements. In order to guarantee the project's long-term viability, we investigated the effects that increasing operations would have on expenses and income.

These economic models were integral to the strategic planning and successful execution of this project. They provided a framework for making informed financial decisions, assessing market viability, and ensuring the project's sustainability and growth. Figure 2.5 represents the economic model of the project.

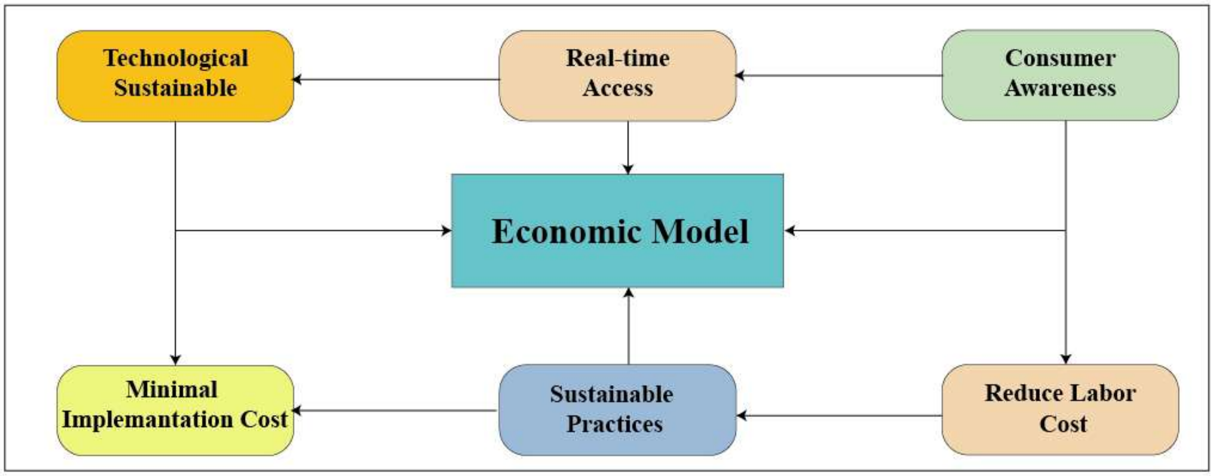


Figure 2.5 Block diagram of economic model of the project.

2.8 Summary

The water meter system project was methodically controlled using core engineering management concepts and image processing. Following the creation of a thorough execution plan, the project scope was defined, along with its goals, limitations, and stakeholder needs. One of the project's strengths was its use of OCR for record-keeping and meter reading, along with its sophisticated automation and remote monitoring capabilities. However, the glass covers on meters and other environmental conditions presented image processing issues. In addition to posing risks due to cost and market competition, the project provided chances for Bangladesh's water meter infrastructure to be modernized. Key management techniques included using Gantt charts to manage the timetable, doing thorough cost analysis, and using P.E.S.T. analysis to evaluate the effect on a wider scale. In order to guarantee its success, the project used a variety of management theories and economic models with an emphasis on professional obligations, moral behavior, and teamwork.

Chapter 3

METHODOLOGY AND MODELING

3.1 Introduction

The accurate measurement and monitoring of water consumption are important for sustainable and efficient utilization. The rise in IoT tech has opened the doors to game changing solution like automated water meter readings. In this project we tried to replace analog water meter with an automatic water meter reading system. In this chapter the methodology and modeling part will be discussed. We started by reading research papers and articles related to our project. This chapter involves whole block diagram, flow chart as well as hardware construction of our project.

3.2 Block Diagram and Working Principle

The main components of this intricate system are a Raspberry Pi 3B+, Pi Camera Module, Relay, and LED, which are arranged thoughtfully on top of a conventional meter. Using the piTunnel website, the Water Service Provider maintains primary control. The Raspberry Pi uses piTunnel to send orders to the Pi Camera Module, which then takes an exact picture of the Conventional Meter. Relay and LED work together to optimize ambient illumination so that the picture that is taken is clear. When an image is successfully captured, the Water Service Provider instructs OCR processing to retrieve digital results, such (00029). Following that, the outcomes are safely saved in the cloud, creating a safe and effective data flow for expedited meter management and analysis. In terms of water meter monitoring, the combination of these elements demonstrates a stable and responsive system.

The project was accomplished by following the steps of Figure 3.1.

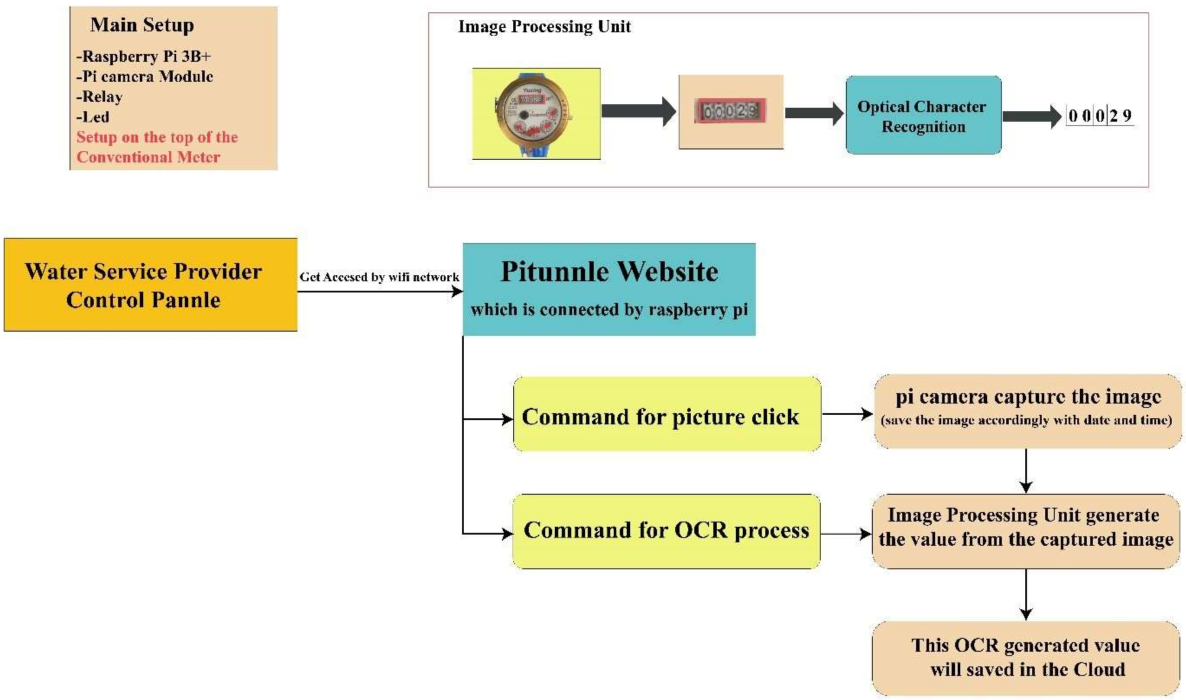


Figure 3.1 Block Diagram of Image Processing Based Meter Reading System

In the following section, we delve into the sophisticated network communication and remote supervision mechanisms of our project.

3.2.1 Raspberry Pi Setup:

During the setup step of the Raspberry Pi, we carefully customized our Pi module to ensure smooth integration into our project. The LED light was attached to the Raspberry Pi using GPIO pin 18 and properly grounded. The camera was carefully connected to the designated camera port at the same time to ensure maximum performance.

In order to display the Raspberry Pi module screen, we made a connection using both the LAN and HDMI connections. This allowed us to conveniently monitor and operate the device from our laptop or PC. This configuration not only guarantees the efficient operation of our project but also creates a strong basis for the next stages of growth. The meticulousness in this setup procedure is crucial to the overall effectiveness and dependability of our Raspberry Pi-based system.

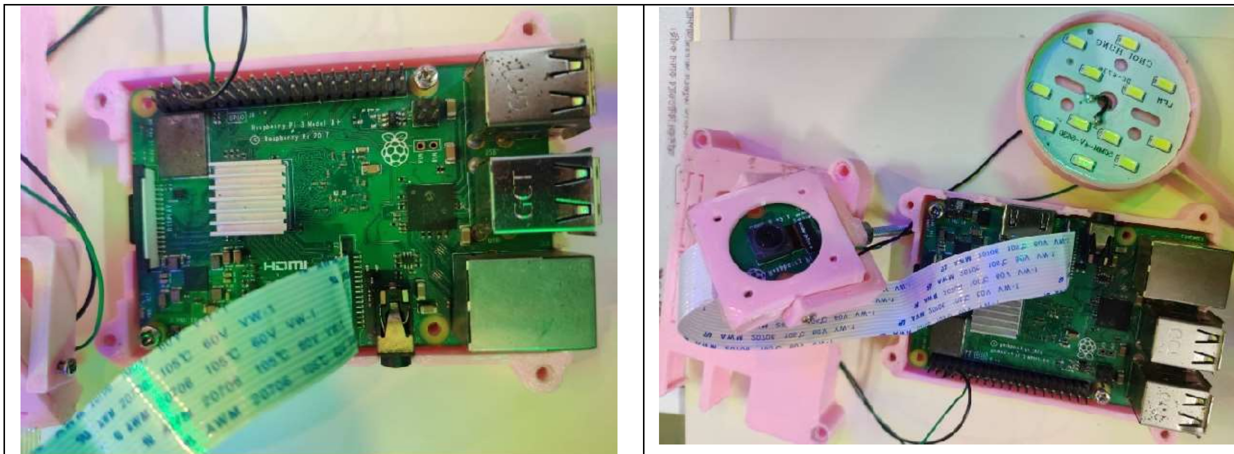


Figure 3.2 Raspberry pi module complete setup

Figure 3.2 shows the Raspberry pi module setup for our project.

3.2.2 Camera Capturing Process:

Our Raspberry Pi can use the offered Python script to take pictures and save them using the camera module. During the first stage, crucial libraries are loaded, such as picamera for camera operations and RPi.GPIO for GPIO control. The GPIO pin (18) is designated for a relay, and the setup_gpio() function establishes the GPIO mode while configuring the relay pin as an output, assuming it operates in an active-low manner. This builds the essential foundation for connecting with external devices.

Regarding the picture capture procedure, the important component is the capture_and_save_image() function. This program utilizes the picamera library to take a picture. It also activates a relay (assuming it is active-low) before the image capture to control external devices. The acquired picture is marked with a timestamp and stored with a distinct filename. The console offers feedback about the successful acquisition of a picture, displaying the filename. Afterwards, the relay is disabled to end the functioning of the external hardware, and GPIO cleaning is performed to free up resources for future script runs.

The GPIO setup is initialized in the main block using the setup_gpio() function, and the picture capture procedure is conducted using the capture_and_save_image() function. The modular nature of this script allows for easy integration into bigger applications, providing a flexible solution for picture capture functionality on a Raspberry Pi.

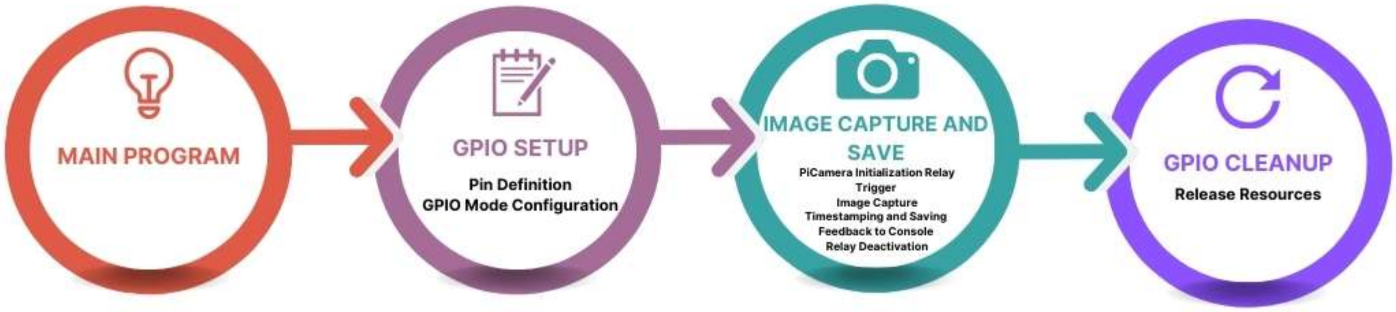


Figure 3.3 Camera Capturing Process

Figure 3.2 shows the camera capturing process of our project.

3.2.3 Image Processing Technique:

In this project, we effectively recognize water meter readings' digits by combining OCR (Optical Character Recognition) with pattern matching methods from image processing. This novel technique seeks to improve the precision and mechanization of the meter reading process.

OCR technology is crucial in the first stage of our system as it is responsible for extracting textual information from photos. The photos, obtained using a Raspberry Pi camera module, undergo preprocessing to improve clarity and minimize noise. Afterwards, OCR techniques are used to identify and extract the numerical digits from the photos, transforming the visual data into text that can be read by machines. This phase is essential for converting the unprocessed visual data acquired from the water meter into a format that is capable of being processed and evaluated by the system.

In the second step, image processing pattern matching algorithms are used to compare the extracted digits with specified patterns in order to identify and validate the numeric values. The use of this pattern matching process improves the system's resilience by verifying the accuracy of the OCR outcomes and minimizing the probability of misunderstanding. The integration of OCR and image processing pattern matching enhances the dependability and effectiveness of our water meter reading system, allowing precise and automated monitoring of water use. This comprehensive solution not only simplifies the process of reading meters but also reduces the need for human involvement, consequently decreasing mistakes and improving the overall efficiency of water resource management.

3.2.4 Remote Access and Data Transmission:

In our project, we use the Pi Tunnel architecture to provide remote access from several networks to our Raspberry Pi module. The Pi Tunnel concept functions as a reliable and effective method for remotely accessing and managing the Raspberry Pi device over the internet, surpassing the constraints of being restricted to a local network.

The Pi Tunnel employs a blend of secure protocols, such as SSH (Secure Shell) and optionally a VPN (Virtual Private Network), to build a secure link between the Raspberry Pi and a distant device. This approach guarantees secure data transmission, safeguarding confidential information while communicating across many networks.

By using the Pi Tunnel framework, we provide effortless use of the Raspberry Pi's capabilities, enabling remote setup, monitoring, and control. This is especially advantageous in situations when there is restricted physical access to the Raspberry Pi, offering flexibility and simplicity in remotely administering the device from any place with internet connection. The Pi Tunnel concept improves the accessibility and usefulness of our Raspberry Pi module, making it a strong choice for applications that need remote administration and control capabilities.

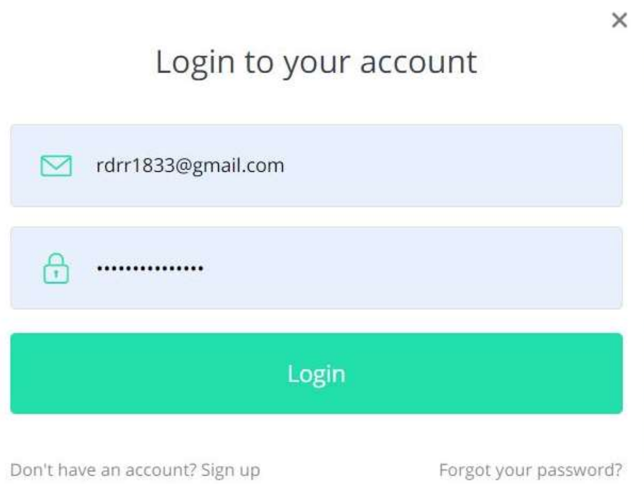


Figure 3.4 Pitunnel interface part-1

This Figure 3.4 shows the pitunnel account login part. This is the first step for to stablish the remote access part of our project.

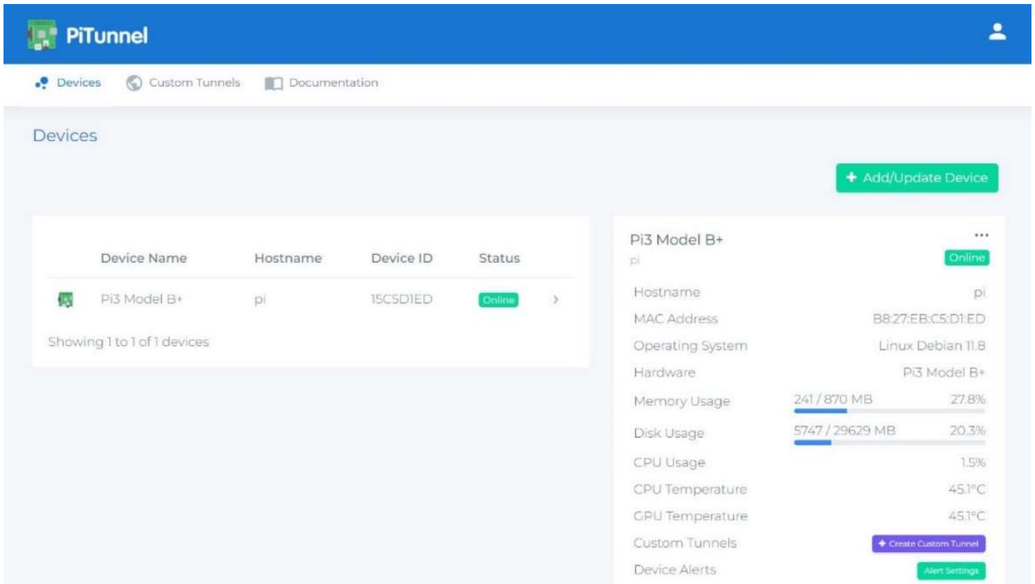


Figure 3.5 Pitunnel interface part-2

The next step involves adding the Raspberry Pi device using the Pi Tunnel link. Upon successful addition of the Raspberry Pi to the Pi Tunnel, the interface resembling Figure 3.5 will be displayed. This interface serves as an indicator that our Raspberry Pi is successfully connected and actively online.

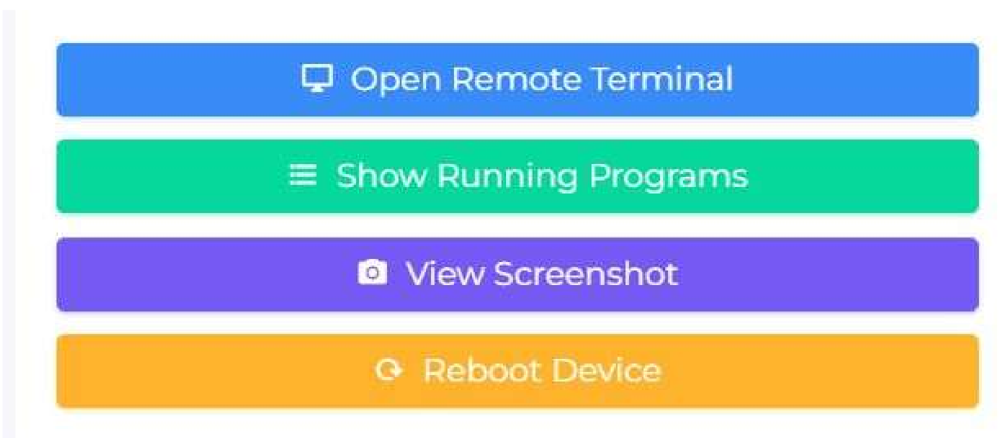


Figure 3.6 Pitunnel interface part-3

Figure 3.6 illustrates the Pitunnel account's remote terminal section, representing the third step in establishing remote access for our project. In this step, we initiate the remote terminal by clicking the "Open Remote Terminal" button. Upon activation, the interface resembling Figure 3.7 is displayed. Within this interface, we are prompted to input our device name and password to gain complete access to our device. Successful completion of this phase grants us the capability to issue commands for tasks such as image capturing and subsequent Optical Character

Recognition (OCR) processes. The remote terminal provides a secure and convenient means for managing our Raspberry Pi device remotely, ensuring seamless execution of various functionalities within our project.

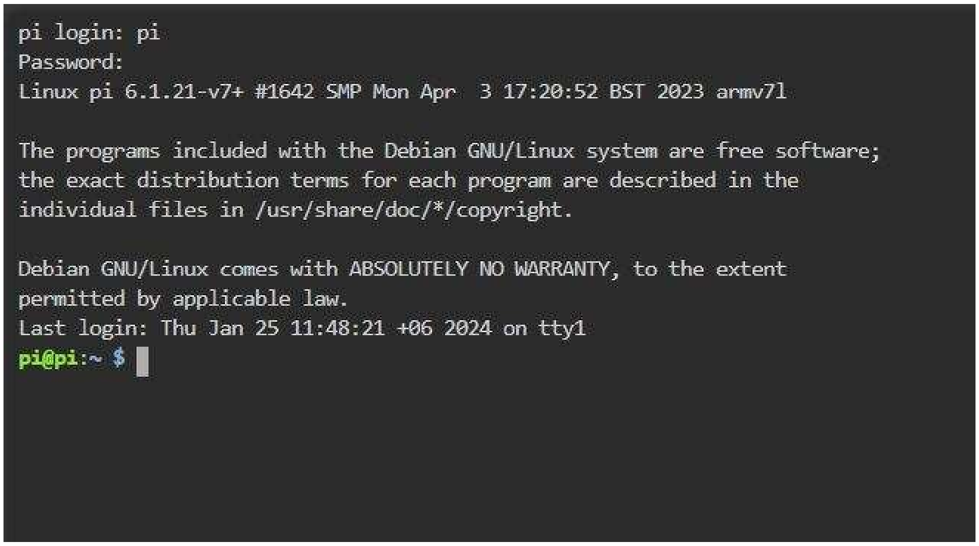


Figure 3.7 Pitunnel interface part-4

In addition, we included RaspController to improve our ability to access remotely. It is crucial to acknowledge that RaspController is explicitly tailored for local network use and is not meant for cross-network utilization. Although it offers a user-friendly interface for monitoring and controlling the Raspberry Pi, its capabilities are limited to the local network.

RaspController enhances our project by providing a handy and user-friendly platform for monitoring and controlling local operations. Users may use its functionalities to engage with the Raspberry Pi, perform instructions, and monitor diverse activities effortlessly inside the local network environment.

Our preferred approach for situations that include remote access across many networks is still the Pi Tunnel concept, as previously mentioned. The integration of Pi Tunnel and RaspController provides a complete solution that addresses both local and remote access requirements, hence enhancing the adaptability and availability of our project based on Raspberry Pi.

3.2.5 Data Store Management for Client/Server:

In our project integration, we link our Raspberry Pi to the Firebase Firestore database, which is a cloud-based data storage platform. This connection is a crucial element for the management and storage of OCR results and billing information. The Firestore database is used to generate a specialized sheet that smoothly connects with our project.

The first step is setting the Raspberry Pi to establish communication with the Firestore database. This is accomplished by using secure authentication protocols, which provide a strong and reliable link between the physical device and the cloud-based database. Afterwards, we establish a methodical document using Firestore to methodically arrange data, linking each input with precise date and time records.

After establishing a successful connection, our project's OCR code is designed to seamlessly communicate with the Firestore database in real-time. When a command is triggered via Pitunnel for OCR, the resultant data, which includes OCR output and payment information, is automatically saved in the Firestore database. The use of chronological structure facilitates the quick retrieval and analysis of data, hence assisting in the thorough maintenance of billing records.

The integration of Firebase Firestore not only enables the easy saving of OCR results but also offers a scalable option for our project. Firestore, being a cloud-based solution, guarantees the integrity and accessibility of data. This allows us to efficiently manage and analyze billing information, making it a strong complement to the overall architecture of our Raspberry Pi-based project.

The integration of robust network communication and sophisticated remote supervision mechanisms was pivotal in the successful implementation of this project. These systems provided the necessary backbone for reliable data transmission, secure and flexible system access, and efficient management of the meter reading process. This multi-layered approach to network communication and remote supervision, encompassing both technical and security aspects, was fundamental in achieving a system that was not only functional but also secure and adaptable to various operational environments. Figure 3.8 shows the algorithm for optimization of the project.

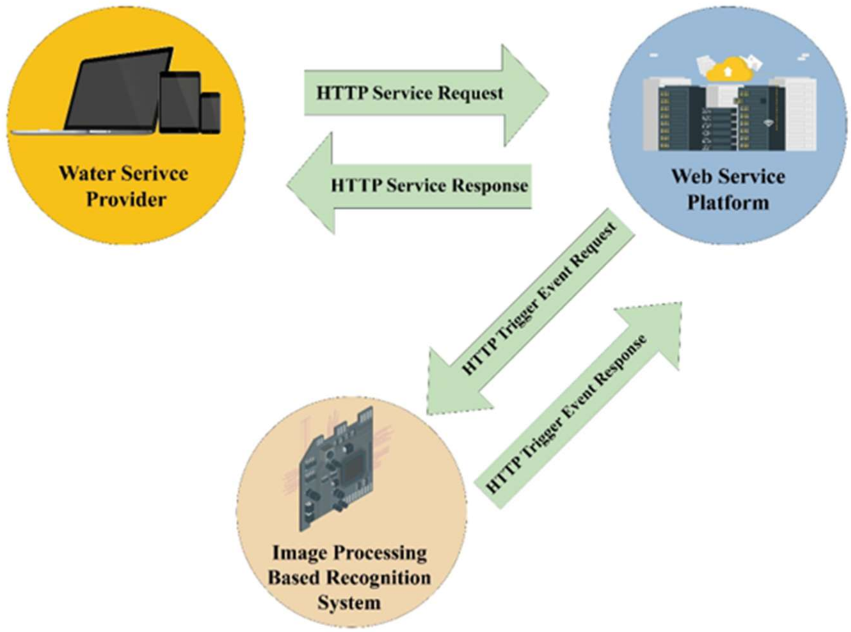


Figure 3.8 Algorithm for Optimization

3.3 Modeling

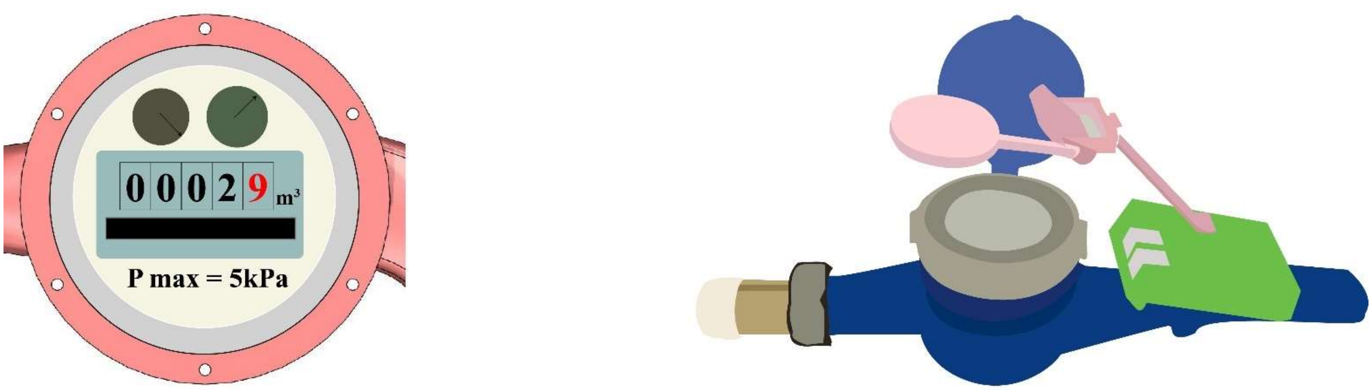


Figure 3.9 2D Modeling of our Model

Figure 3.9 Shows the hardware model of the project. The hardware component of the proposed system comprises a Raspberry Pi project that has been affixed to the surface of a water meter. An LED light, a Raspberry Pi 3B+, and a Pi Camera are the essential components. The Raspberry Pi functions as the primary processing device, coordinating the image capture and processing operations. By virtue of being an essential hardware element, the Pi

Camera facilitates the visual acquisition of data from the water metre. In order to achieve superior image quality, an LED light is integrated, offering additional illumination to facilitate the capturing of clear and intricate details.
The software component of the paradigm comprises the Raspberry Pi's executed programming and control logic. The system is specifically engineered to acquire images utilizing the Pi Camera, and the software module incorporates image processing and storage functionalities. The software is developed using Python, a flexible programming language, which incorporates libraries like OpenCV for image processing and Pi Camera interfacing.

3.4 Summary

This chapter, dedicated to methodology and modelling, centers on the construction of an automated water meter reading system. To accomplish this, a Raspberry Pi 3B+, Pi Camera Module, Relay, and LED are utilized. Situated atop a traditional meter, these elements are coordinated via the piTunnel website, thereby granting authority to the Water Service Provider. The block diagram of the system provides a visual representation of its architecture, showing the sequential execution of various components such as image capture, OCR processing, and secure cloud storage of digital outcomes. The text highlights the complex network communication mechanisms, providing specifics regarding the implementation of Wi-Fi for data transmission and encryption methods to guarantee the security of data transfer.

The client/server architecture is implemented so that a scalable and adaptable data request system can be utilized by client applications; Raspberry Pi serves as the server in this configuration. Implementation of Secure Shell (SSH) strengthens remote access by facilitating management and monitoring in real time, which is critical for maintaining system integrity. The chapter concludes by discussing 2D modelling, which emphasizes the effective processing of images through the integration of software logic and hardware components. Python, in conjunction with OpenCV libraries, serves as the fundamental framework of the software component, showcasing a thorough methodology and approach to modelling. By prioritizing security, adaptability, and real-time accessibility, this multi-layered system not only guarantees operational efficiency but also assures functional efficiency, thereby constituting a resilient solution for automated water meter readings in various operational environments.

Chapter 4

PROJECT IMPLEMENTATION

4.1 Introduction

The project discussions have been completed up to this point, and the next phase involves the practical implementation of the project. This chapter covers a range of subjects related to the completion of a project. The chapter is divided into multiple sections, starting with discussing the required equipment and components. Afterwards, the implementation of the project. The implementation process involves two primary tasks: simulation and hardware implementation. The simulation phase is the preliminary step prior to project execution, making it an important task. The simulation was executed according to the plans, utilizing the PROTEUS software. The hardware model was constructed after successfully finishing the simulation. The hardware model was finalized by utilizing the approaches presented in Chapter 3.

4.2 Required Tools and Components

Below is the inventory of the necessary equipment and components for the project.

1. Raspberry Pi 3B+.
2. Pi Camera Module V2.
3. Pi Adapter.
4. 2-Channel Relay Module.
5. LEDs.
6. MicroSD Card.
7. MicroSD Card Reader.
8. HDMI Cable.
9. Cooling Fan

10. 3D Modeled Case.

11. Battery.

12. PiTunnel

13. RaspController

14. Firebase

All these components along with the necessary software were used to complete the project. The following is a detailed explanation of each component used during the project.

4.2.1. Hardware Components

- **Raspberry Pi 3B+**

The Raspberry Pi 3B+ is the final version of the third-generation single-board computer from the company Raspberry Pi. It is a multifunctional microcomputer that has become popular due to its small proportions and impressive capabilities. The 3B+ provides improved performance in comparison to its previous versions, thanks to its 1.4GHz quad-core ARM Cortex-A53 processor and 1GB RAM. The device includes integrated wireless networking via both Wi-Fi and Bluetooth, allowing for convenient use in a wide range of applications. The board is equipped with four USB ports, a 40-pin GPIO header, HDMI output, an Ethernet port, and a microSD card slot for storage. The Raspberry Pi 3B+ is well-suited for a wide range of tasks, including DIY electronics, programming experiments, operating as a media center, or functioning as a tiny server. The following is the pinout of the Raspberry Pi. Figure 4.1 is the pinout of the Raspberry pi.

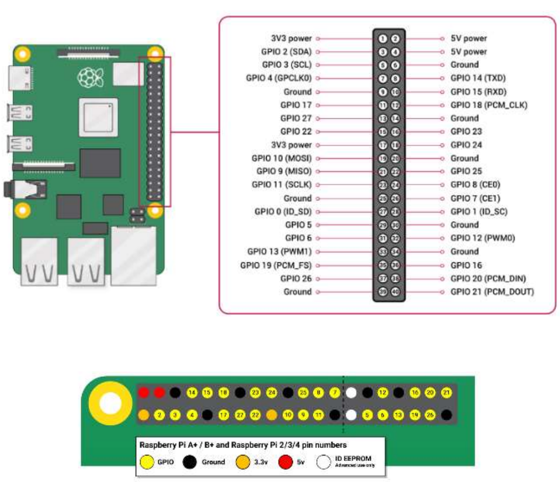


Figure 4.1 Raspberry Pi 3B+ Pinout [20]

According to the company Any of the GPIO pins can be designated (in software) as an input or output pin and used for a wide range of purposes.

- **Pi Camera Module V2**

The Pi Camera Module V2 is an 8-megapixel camera designed for Raspberry Pi. It captures high-quality images and videos, offering user-friendly features for beginners and advanced capabilities for enthusiasts. With support for various video modes and a simple connection via a 15cm ribbon cable to the Raspberry Pi's CSI port, it's a versatile imaging solution for a range of projects. The Pi camera module can be seen in Figure 4.2.

Figure 4.2 Pi Camera Module V2 [21]

- **Pi Adapter**

The Pi Adapter is an important tool that gives Raspberry Pi devices a power supply. It is an important part for powering and energizing the Raspberry Pi. Figure 4.3 shows an example of adapter for raspberry pi.

Figure 4.3 Adapter for Raspberry Pi [22]

- **2-Channel Relay Module**

The 2-Channel Relay Module is a flexible device that enables Raspberry Pi or other microcontrollers to manipulate high-voltage devices. Featuring two autonomously regulated channels, this device is perfect for home automation and electronics projects that necessitate remote control of electrical appliances. A two channel relay module can be seen in Figure 4.4.

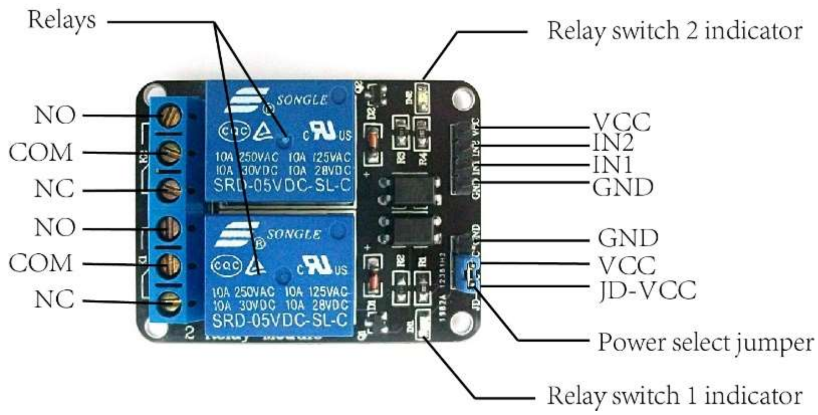


Figure 4.4 Two Channel Relay Module [23]

- **LEDs**

An LED is a semiconductor device that generates either infrared or visible light when an electric current is applied to it. Visible light-emitting diodes (LEDs) serve as indicator lamps in many electronic gadgets, as well as rear-window and brake lights in automobiles. Here's an example of LEDs in Figure 4.5.

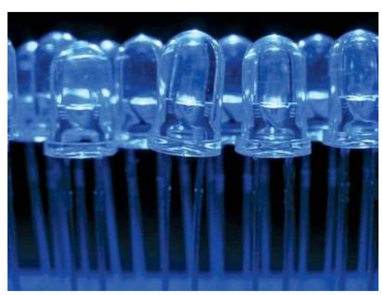


Figure 4.5 LED lights [24]

- **MicroSD Card and MicroSD Card Reader**

A MicroSD card is a storage device used for data storage, like an electronic memory card. The MicroSD card is important for the Raspberry Pi as it acts as the primary storage medium, including the operating system and essential data required for the computer to operate. Therefore, it is an important part of the Raspberry Pi because it lets the device start-up and run programs. A MicroSD card reader is a device that establishes a connection between a

MicroSD card and a computer, enabling the transmission of data, formatting, and the loading of files onto the card. MicroSD card and Card Reader can be found similar to Figure 4.6.

Figure 4.6 MicroSD Card and Card Reader [25]

- **LAN Cable**

A LAN cable connecting a Raspberry Pi provides a reliable and high-speed wired network connection, facilitating data transfer, communication, and internet access for the device. LAN cable looks like Figure 4.7.

Figure 4.7 LAN Cable [26]

- **Heat Sink**

A cooling fan is an active cooling solution used in Raspberry Pi to dissipate heat generated by the processor. In this project, the cooling fan is used to prevent the Raspberry Pi from overheating during prolonged or intensive tasks, enhancing the overall performance and longevity of the device. Heat sinks similar to Figure 4.8 was used.

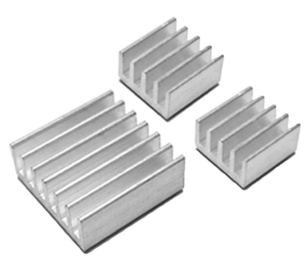


Figure 4.8 Heat Sink [27]

8.2.2 Required Software's

- **Proteus Design Suite**

Proteus, created by Labcenter Electronics, is a versatile electrical design automation (EDA) program extensively utilized for circuit design and simulation. The interface of the software is designed to be easy for users to navigate and understand. It allows users to create complex circuits, and the simulation capabilities are strong, allowing for detailed examination before building the circuits. Proteus stands out in its ability to simulate microcontrollers, providing users with the opportunity to virtually create and evaluate firmware code. The program additionally enables PCB design, provides 3D visualization for physical layouts, and incorporates virtual instruments for real-time analysis. Proteus is a favored option for circuit design among electronic enthusiasts, students, and professionals due to its extensive collection of components.

Figure 4.9 Proteus Design Suite [28]

- **PiTunnel**

Utilising a secure and user-friendly method to remotely manage Raspberry Pi devices, PiTunnel is an indispensable application for Raspberry Pi enthusiasts. PiTunnel's intuitive web interface streamlines the intricacies of remote access, enabling users to interact and remotely manage their Raspberry Pi projects without interruption from any geographical location that has internet access. Rendering it a dependable option for both amateur endeavours, Internet of Things applications, and professional growth, the service's robust security attributes, such as encryption protocols, safeguard the privacy of data throughout remote exchanges. Enhancing the usability and accessibility of Raspberry Pi devices across a wide range of applications is made possible by the adaptability and simplicity of PiTunnel.

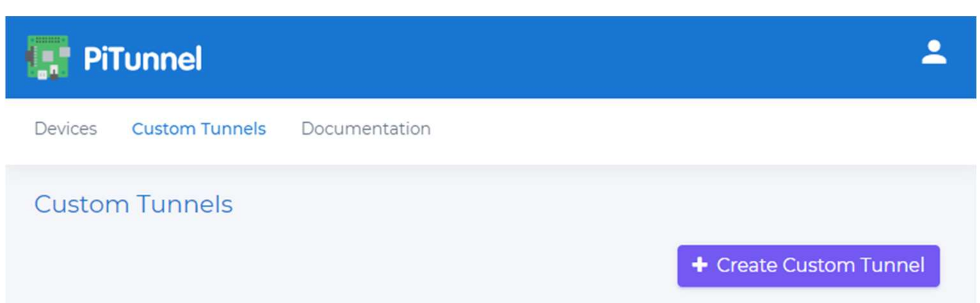


Figure 4.10 PiTunnel Design Suite [29]

- **RaspController**

RaspController is a multifunctional and intuitive software application specifically developed to optimise the administration and regulation of Raspberry Pi devices. By utilising RaspController's user-friendly interface, individuals are able to remotely oversee and manipulate a multitude of Raspberry Pi project-related elements. Including real-time system status updates, file system navigation, process management, and GPIO control, the application provides both novice and experienced Raspberry Pi enthusiasts with a comprehensive toolkit. RaspController greatly streamlines the process of interacting with Raspberry Pi devices, thereby improving the usability and accessibility of a wide array of projects, including but not limited to educational initiatives and home automation.

Figure 4.11 RaspController [30]

- **PyCharm (Python IDE)**

PyCharm is a popular Python Integrated Development Environment (IDE) developed by JetBrains. Known for its user-friendly interface and powerful features, PyCharm offers code completion, debugging tools, version control integration, and support for various frameworks, making it a comprehensive environment for Python development. PyCharm was used to do all the simulations utilizing python.

Figure 4.12 PyCharm IDE [31]

- **Firebase**

Firebase, a robust platform developed by Google, provides a collection of multifunctional elements that facilitate the efficient creation of applications. The Realtime Database guarantees immediate synchronization of data, whereas Authentication streamlines the process of securely logging in users through multiple providers. A scalable NoSQL database solution is offered by Cloud Firestore, while serverless execution of downstream code is made possible by Cloud Functions. These are complemented by cloud messaging for cross-platform notifications, cloud storage for secure file management, and cloud hosting for efficient web deployment. It is critical to priorities security protocols, SDK integration, and API usage in order to ensure an effective implementation. Fueled by its ability to facilitate the creation of scalable, responsive applications, Firebase is a pillar in contemporary application development.

Figure 4.13 Firebase [32]

4.3 Implemented Models

This project involves the integration of both hardware and software components, with the focus being on optical character recognition (OCR) of meter images, where OCR plays an important part. The primary objective involves simulating the prototype and establishing the groundwork for succeeding phases. Subsequently, a range of pre-processing techniques were applied to improve the capabilities of image processing. The final stage necessitated the integration of all elements to carry out the hardware implementation. This systematic methodology guarantees a thorough and organized advancement towards accomplishing the project's primary objective of optical character recognition from meter images.

4.3.1 Simulation Model

The Simulation model of our project is-

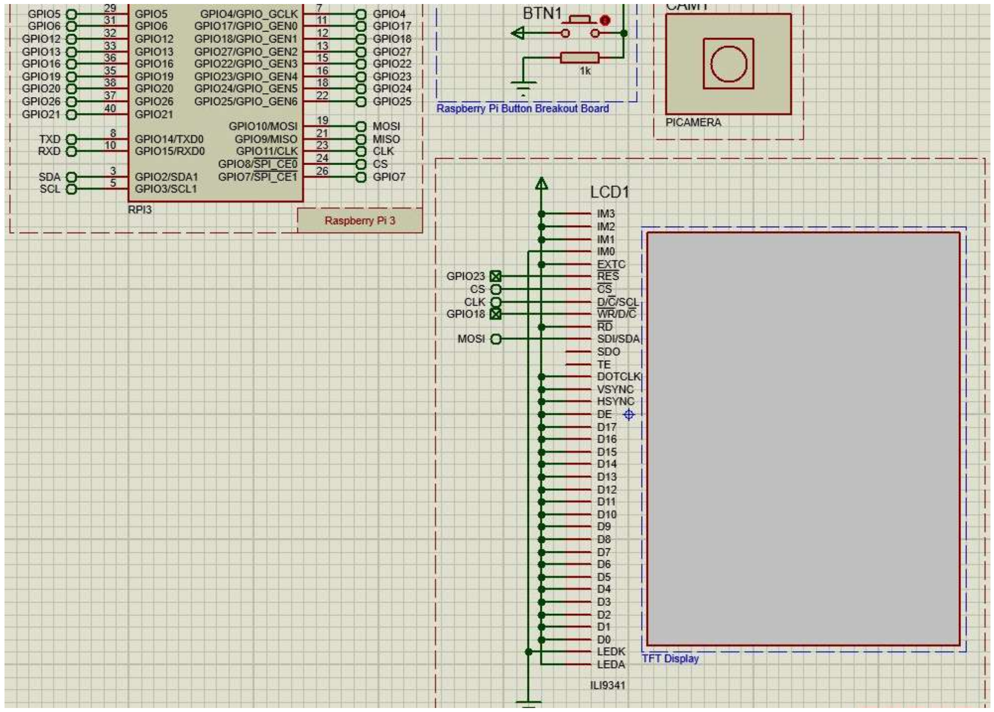


Figure 4.14 Circuit Diagram of the simulation model

The figure 4.14 shows the simulation experiment integrates a camera, a push button, and an antiseptic screen with a Raspberry Pi. This integration facilitates image capture and display. Key steps in the project include:

- Component Selection: Important add-ons, such as a camera, screen, and button, are picked with care to ensure that they work well together and complement the project.
- Component Integration: By systematically adding these elements to the project, flawless operation and interaction are guaranteed.

- Configuration using Visual Designer: To carefully organize and configure the chosen components, a visual designer tool is used. A thorough flowchart that explains each component's function and behavior inside the system serves as the configuration's guide.
- Display Functionality: The project's main goal is to show an image on a TFT LCD screen. In order to exhibit a picture as well as possible, this activity entails uploading an image file into the system and adjusting the display parameters.
- Camera Setup and Activation: The camera, which is designed to take pictures when a button is pushed, is a key component of the project. Ensuring the camera's operational compatibility inside the whole system is a key component of the project.

The simulation process demonstrates a comprehensive approach to integrating and configuring key electronic components, focusing on achieving specific image capture and display objectives in a controlled simulation environment. The project effectively showcased the integration and interfacing of critical elements, including a push button, an antiseptic screen, and a camera, with a Raspberry Pi. This configuration permitted the fundamental operations of image capture and display. A visual designer was employed to precisely define the behavior of each component, thereby facilitating the development of an all-encompassing flowchart for the simulation.

One critical element of the simulation involved the exhibition of an image onto a TFT LCD screen. The procedure involved importing a particular image file into the system and adjusting the display configuration to achieve the most effective visualization. The camera, which was an essential component of the undertaking, was programmed to produce images when the push mechanism was engaged. This function was of the utmost importance; when the button was pressed, the camera immediately began to capture an image, which was subsequently displayed on the screen. The system was skillfully programmed to implement the image capture and display sequence in accordance with the button's status.

The simulation outcomes underscore the effective integration and operational capabilities of the system components.

4.3.2 Hardware Model

This is the first phase of our model-

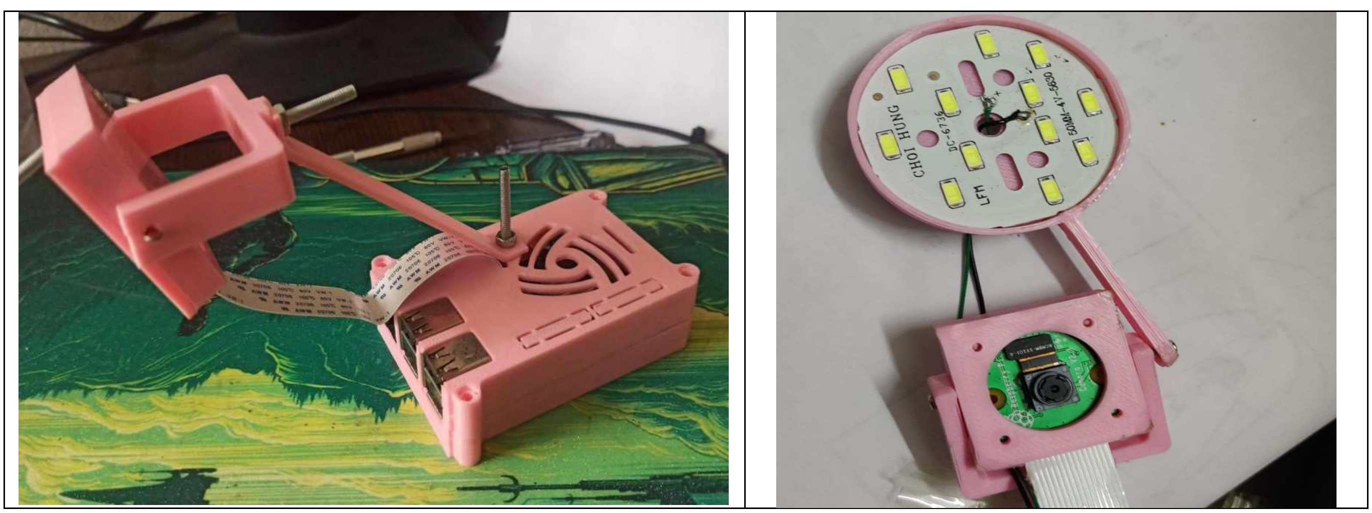


Figure 4.15 Hardware Part (1)

Figure 4.16 Hardware Part (2)

The foundational components of our automated water meter reading system are strategically assembled atop a conventional meter during the initial phase of hardware modelling. In figure 4.15 it shows that a Raspberry Pi 3B+ encased in a protective cover a Pi Camera Module and a LED lighting comprising this configuration. And figure 4.16 shows the water meter, which is the meter we use in our project.The Raspberry Pi functions as the primary processing device, coordinating the acquisition and analysis of images. Precise data collection from the water meter is facilitated by the Pi Camera. The incorporation of LED lights is essential for enhancing the illumination in the environment and guaranteeing the precision of the images captured.

This is the final phase of our model-

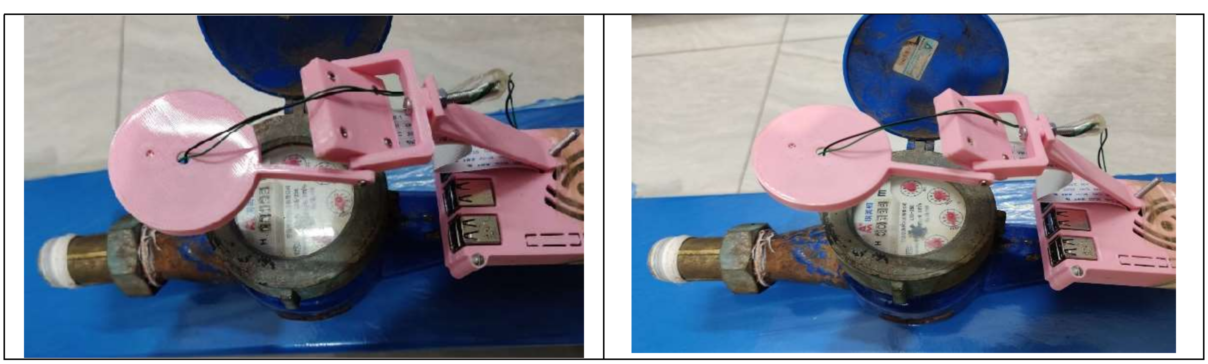


Figure 4.17 Top View of Hardware Model

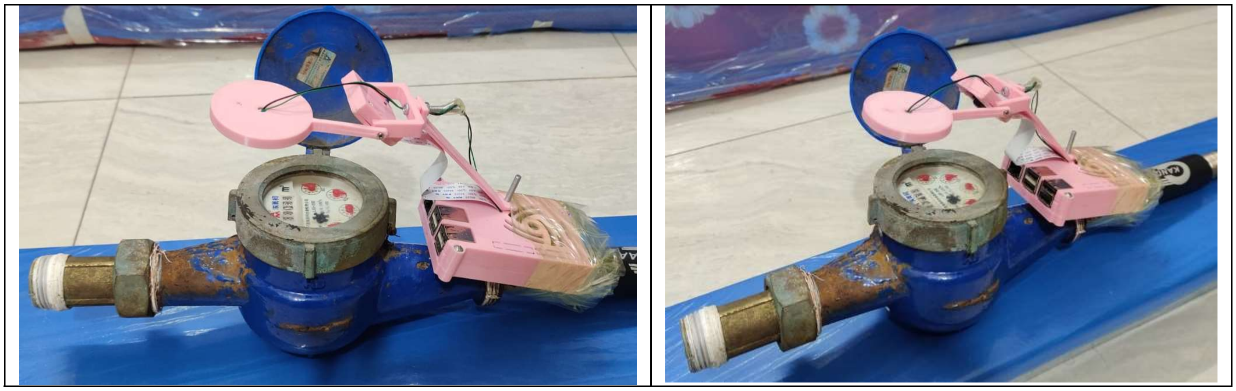


Figure 4.18 Side View of Hardware Model

In figure 4.17 and 4.18 shows a comprehensive visual depiction of the hardware in its second phase is presented in the image above through the use of two distinct viewpoints: an oblique view and a lateral view. Situated in a controlled manner atop the water meter, our system exemplifies the seamless integration of critical elements. The system comprises a Raspberry Pi central processing unit, which is intricately linked to a Pi camera and LED lighting that are arranged in a strategic manner. Placing emphasis on the placement precision, the upper view provides a bird's-eye view of the spatial configuration of the system. Conversely, a cross-sectional view of the Raspberry Pi, Pi Camera, and LED lighting is observed in the side view, which offers valuable insight into their vertical arrangement.

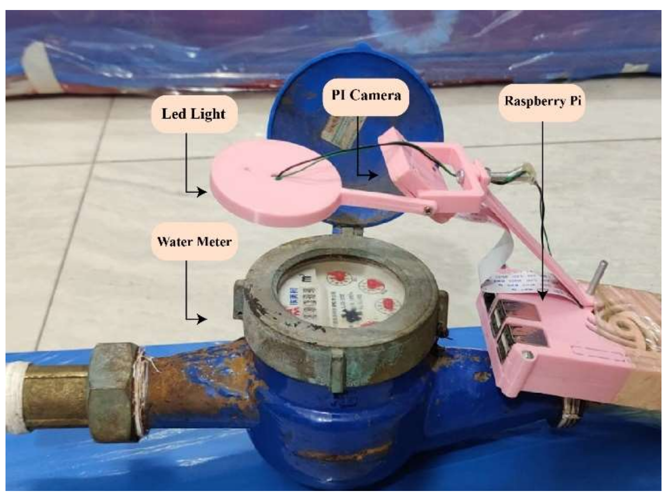


Figure 4.19 Labeling of Hardware Model

By highlighting the interdependent relationship between the advanced technology components and the conventional water meter infrastructure, this dual-angle depiction aids the reader in comprehending the physical configuration. In aggregate, these visuals succinctly illustrate how state-of-the-art hardware components are seamlessly incorporated into our automated water meter reading solution. In figure 4.19 shows a complete labeling of our hardware model.

4.4 Engineering Solution in accordance with professional practices

The suggested approach for our project is a paradigm change away from the conventional manual water metering system and toward an advanced water metering system based on image processing. The shift entails converting the current infrastructure into a digital format, using modern image processing technology to improve the precision and effectiveness of water meter readings. Our methodology follows professional engineering methods by using creative methodologies that combine technical principles with insights from cutting-edge research.

Our technical solution incorporates cloud vision technology to effectively analyze optical character recognition (OCR), with a special focus on overcoming power consumption obstacles. This strategy implementation adheres to engineering standards, showing a dedication to both technical proficiency and ecological sustainability. The project upholds ethical principles, acknowledging the engineer's duty to prioritize the safety and well-being of the public. This dedication is evident in the integration of cloud-based technology, which guarantees the safe and dependable administration of data.

In addition to the technical aspects, our project adheres to engineering standards by adopting a comprehensive viewpoint. The system's primary objective is to improve operational efficiency, resulting in a decrease in expenses related to manual procedures. From a social perspective, it promotes openness and precision in invoicing, cultivating trust between customers and service providers. Our strict adherence to criteria demonstrates our dedication to providing a Professional Engineering Solution that has a good influence on both society and culture.

Furthermore, the project's commitment to being environmentally friendly is emphasized, underscoring its role in promoting sustainable engineering methods. This method aligns with current engineering standards that prioritize environmentally sustainable solutions. To summarize, our project adheres to engineering standards and tackles technical obstacles while also taking into account wider social, economic, and environmental consequences. This demonstrates our commitment to creating a full Professional Engineering Solution.

4.5 Summary

The chapter provides a comprehensive account of the pragmatic execution of a project that amalgamates software and hardware elements to effectively recognize meter images using optical character recognition (OCR). It then describes the software and hardware required, including PROTEUS and PiTunnel, as well as the camera module, relay modules, LEDs, and Raspberry Pi 3B+. Utilizing its sophisticated processing capabilities and connectivity options, the Raspberry Pi 3B+ functions as the central device. Acquiring high-quality images for OCR is dependent upon the camera module.

In order to virtually model the circuit prior to its physical construction, the implementation includes a simulation phase utilizing the PROTEUS software. Following this, the hardware phase commences, during which the Raspberry Pi and camera module are physically assembled into a case for protection and LEDs are utilized to provide adequate illumination.

Additionally, two hardware models are described in the chapter. Establishing the Raspberry Pi and camera on a standard meter, the initial model establishes the foundation. Focusing on the integration and placement of every component, the second phase offers a comprehensive view of the system.

From manual reading to an image processing-based system, the engineering solution for the undertaking evolves. This study highlights the significance of utilizing cloud vision technology and OCR in order to improve the efficacy and accuracy of water meter readings. Taking into account ethical standards, public safety, and environmental impact, this solution has been developed in accordance with professional standards. A model of responsible engineering, the outcome is a system that is both socially and economically advantageous, while also fostering trust and transparency between service providers and clients.

Chapter 5

RESULTS ANALYSIS & CRITICAL DESIGN REVIEW

5.1 Introduction

This paper focuses on the pivotal segment of the Image Processing Based Water Meter Reading System. The integration of image processing techniques into water meter reading systems represents a significant advancement in smart utility management. This chapter presents the project's result analysis and critical design review with appropriate discussion. All potential outcomes are discussed in this after the hardware prototype was implemented after the simulation part was completed.

5.2 Results Analysis

This critical segment recognizes the equivalent importance attributed to both software and hardware elements within the Image Processing-Based Water Meter Reading System. Although the hardware's operation typically requires less simulation, the software application, specifically the Optical Character Recognition (OCR) model, is crucial and requires thorough simulation examination. The simulated results assess the effectiveness of the OCR model in precisely deciphering metre readings. Concurrently, the hardware outcomes segment provides an exhaustive examination of the ideal execution of the complete project framework. The effective integration of hardware and software components is crucial to the achievement of the project's objectives, exemplifying the mutually beneficial partnership in which the hardware components execute the OCR model precisely. The transformative effect of the system on conventional water meter readings is guaranteed by the synergistic integration.

5.2.1 Simulated Results

During the early stage of our project simulation, the circuit diagram acts as the fundamental basis, including essential elements such as the Raspberry Pi, a Pi camera, a push button, and a display. The configuration replicates the physical hardware arrangement used in our Image Processing-based Water Meter System. The simulation replicates the interaction between these components to demonstrate the smooth integration envisioned for our project.

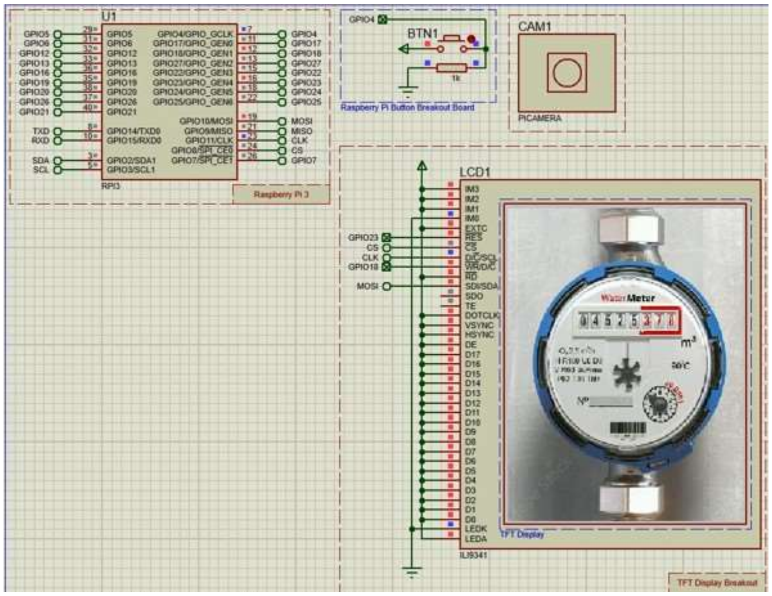


Figure 5.1 Simulation Model of our project

The Raspberry Pi serves as the core component of the simulation, overseeing and coordinating the whole process. Upon pressing the push button, which serves as a command to take a picture, the Pi camera promptly captures an image, replicating the functionality seen in the real world. The generated picture is then shown on the screen, offering a visual depiction of the collected data. The figure 5.1 shows the simulation process of model.

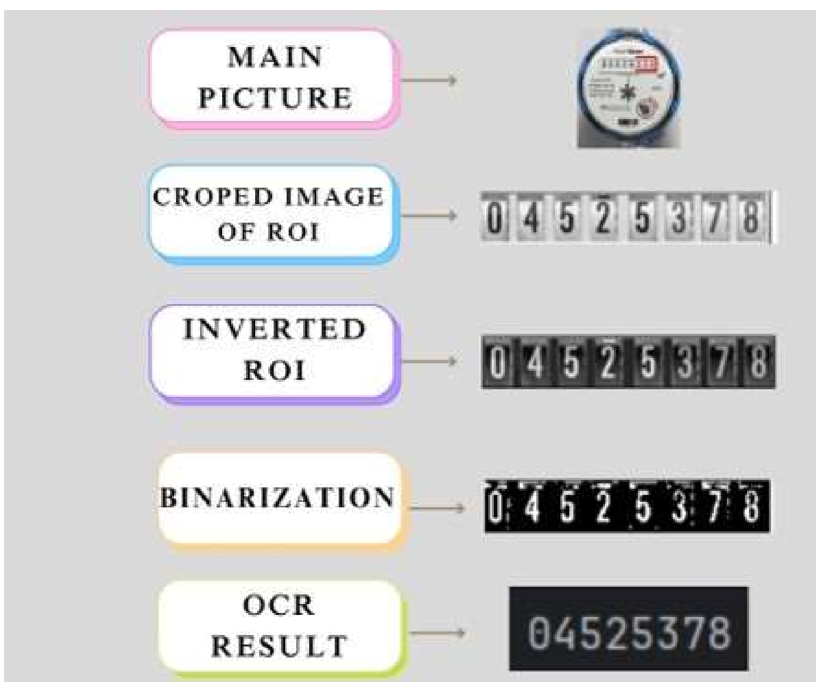


Figure 5.2 Simulation Result of our project

In the figure 5.2 shows of our project simulation, we delve into the outcome of employing Optical Character Recognition (OCR) methods. The simulated scenario emulates the OCR process on the captured image, showcasing the system's ability to recognize and extract relevant text, such as numerical digits from the water meter.

The graphic illustrates a sequential Optical Character Recognition (OCR) procedure. Below is a detailed analysis of each individual step:

- Main Picture: The first image depicts a meter reading consisting of a sequence of numbers.
- Cropped ROI Image: The Region of Interest (ROI) has been extracted from the original image by removing the surrounding areas. This process involves extracting the specific portion of the picture that holds the relevant information, which in this instance refers to the numerical display of the meter.
- Inverted ROI: The ROI is then reversed by cropping the picture. Utilizing inversion in this context may effectively interchange the colors to enhance contrast, hence facilitating the following process of recognition.
- Binarization: This process changes the inverted region of interest (ROI) into a binary image, where the picture is changed into a two-color representation, usually black and white. The purpose of this process is to streamline the picture, minimizing it to just the vital data required for identification.
- OCR Result: The OCR algorithm successfully retrieves the numerical data from the binarized picture, yielding a string of numbers "04525378" that corresponds to the recognized text in the image.

The figure depicts a standard OCR workflow in which a picture containing text undergoes a series of transformations to prepare it for text recognition. This procedure ultimately results in the extraction of the text data.

5.2.2 Hardware Results

The focal point of this project revolves around image processing, with a primary emphasis on Optical Character Recognition (OCR). The objective was to develop a model capable of effectively processing images obtained from various water meters. In pursuit of this goal, a comprehensive dataset comprising images of six distinct water meters installed in diverse household conditions was collected. Subsequently, these images were subjected to our image processing model, with the aim of deriving accurate readings from the meters. Here, three meters are placed above and three is placed below the tank.

In this part, for result analysis, we used a mobile camera to capture the meter.

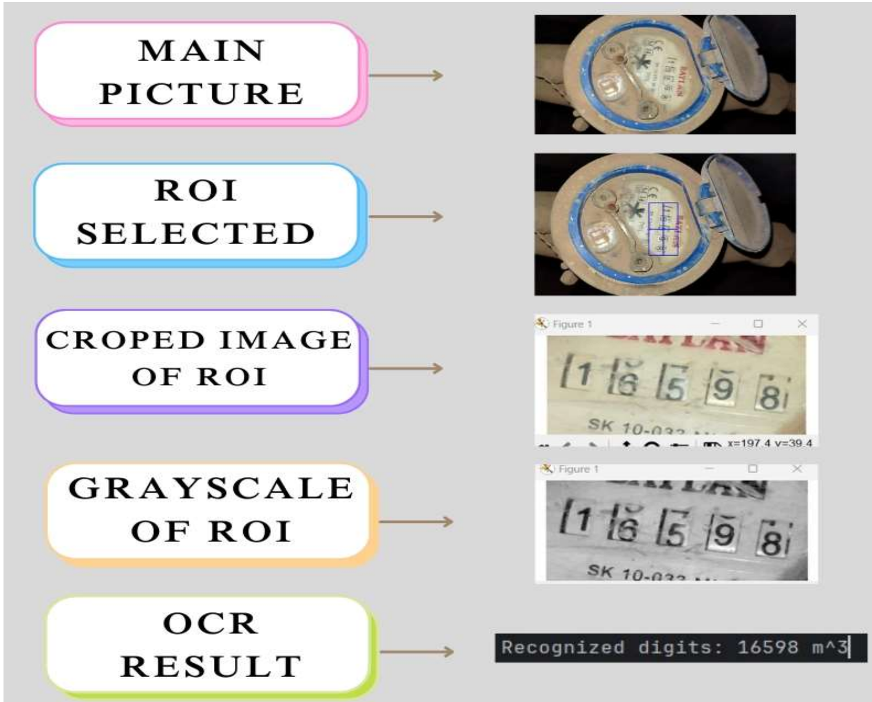


Figure 5.3 Result of Sample 1 (Good Lighting)

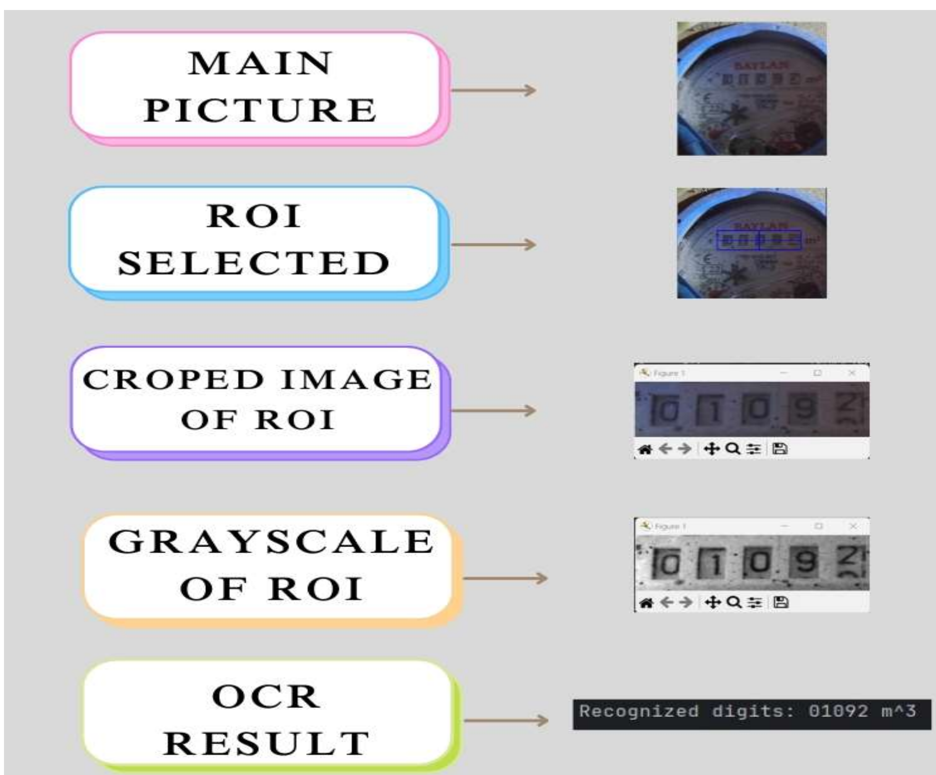


Figure 5.4 Result of Sample 2 (Low light)

Figure 5.3 shows the result of sample 1. It was captured under optimal lighting conditions, yielding exceptional picture quality and accurate processed results. Figure 5.4 shows the result of Sample 2, it taken under low-light conditions with consistent camera quality from Sample 1, aimed to assess the impact of lighting on the outcomes. Notably, the processed output for both samples demonstrated accuracy.

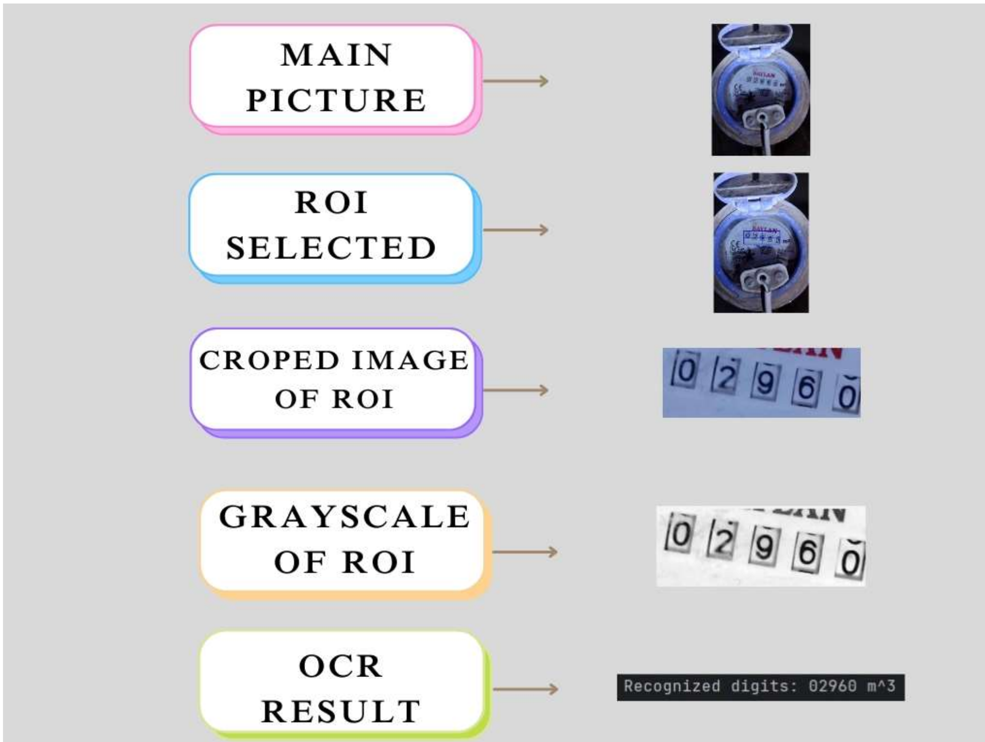


Figure 5.5 Result of Sample 3 (Dark place, low light)

Figure 5.5 shows the result of sample 3, depicted, it was acquired in a dimly lit environment. Despite the challenging lighting conditions, maintaining high camera quality resulted in an accurate image processing outcome. These observations from the three samples collectively indicate that sustaining superior camera quality contributes to achieving accurate results across varied lighting conditions.

Following the above-ground meter sampling, subsequent samples were collected from meters located below the ground.

Figure 5.6 Result of Sample 4 (Good light)

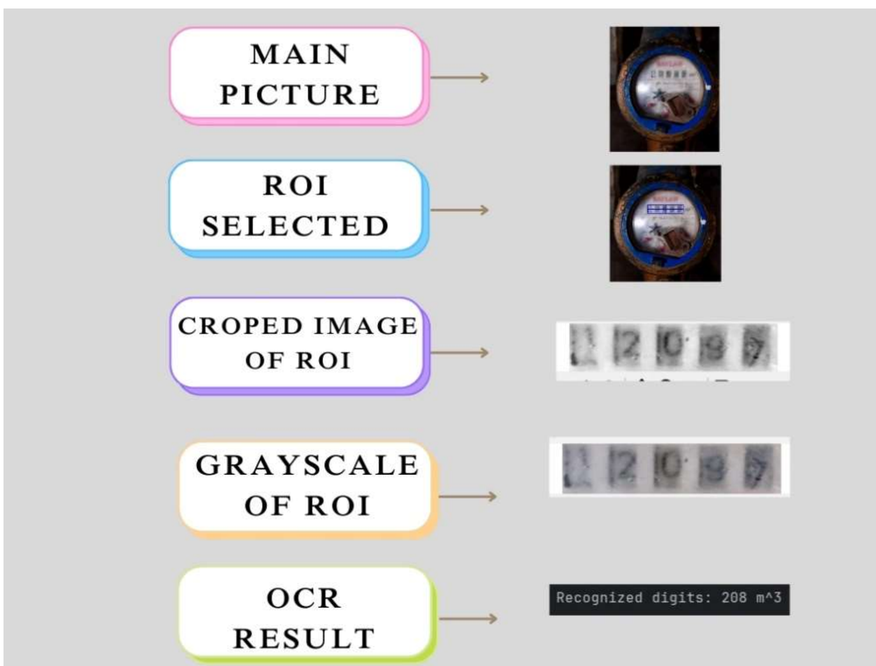


Figure 5.7 Result of Sample 5 (Blur glass)

Figure 5.6 shows the result of sample 4, obtained from a meter in a subsurface position, displayed reflections in the glass, causing distortion in a few digits and leading to unsuccessful image processing. Nevertheless, the model successfully recognized the first four digits, with slight distortion observed in the digit '9.' And figure 5.7 shows the result of sample 5. In the case of Sample 5, the meter exhibited blurred glass, resulting in inaccurate image processing.

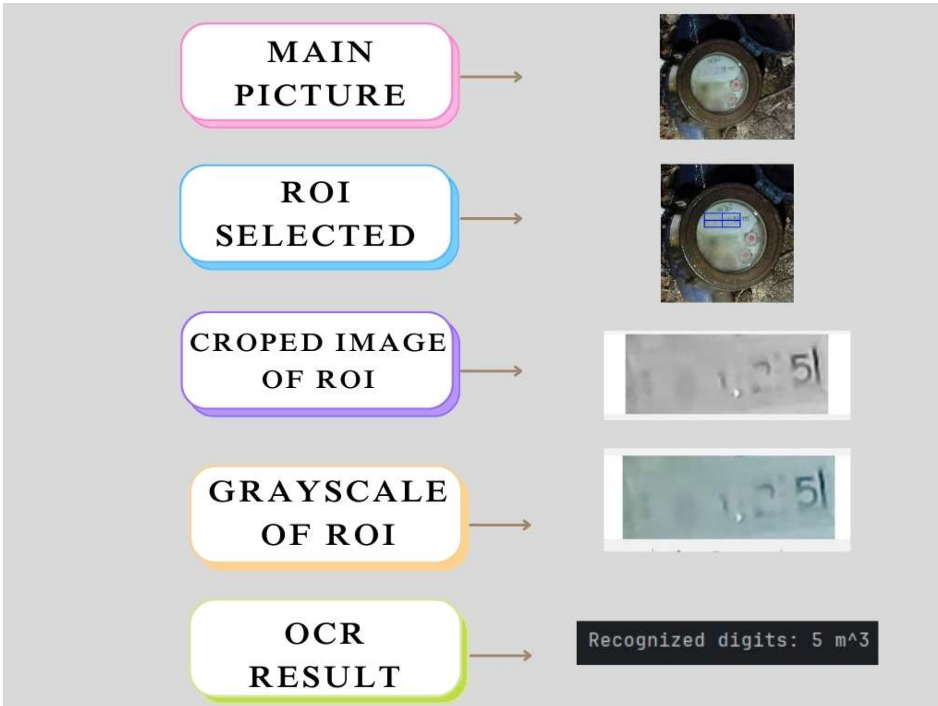
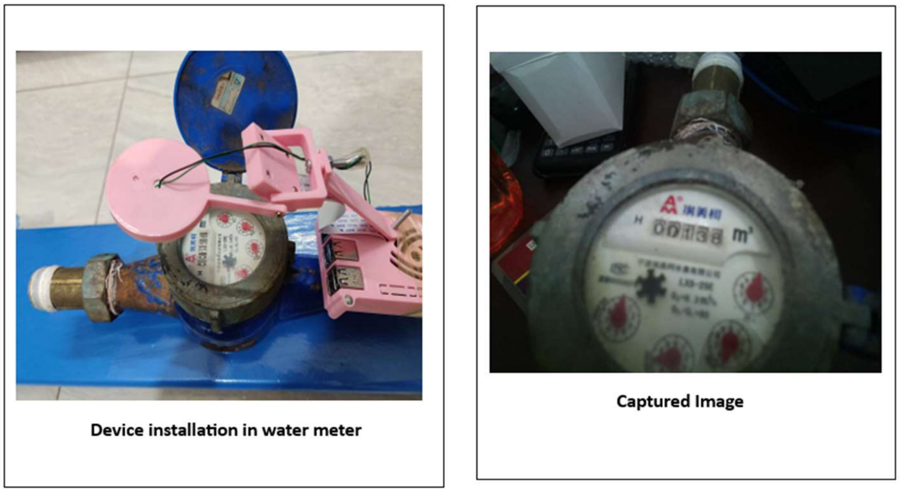


Figure 5.8 Result of Sample 6 (Underground, blur glass, dirt)

Figure 5.8 shows the result of sample 6. It was sourced from a household with the meter positioned beneath a tank, significantly elevated from the ground. As depicted in the meter dial appeared heavily soiled and barely legible to the naked eye. Despite the challenging conditions, the model successfully detected the last digit.
Analysis of result of samples 4, 5, and 6 leads to the conclusion that meters placed below ground present critical conditions, making digits challenging to detect accurately through the image processing model.

Following the integration of the hardware module, a sample meter was collected to facilitate the research investigation. Utilizing the Raspberry Pi camera connected to the module, images were captured. The acquisition involved capturing images from various angles, a process undertaken to meticulously analyze the results and ascertain the optimal camera position for subsequent data collection.



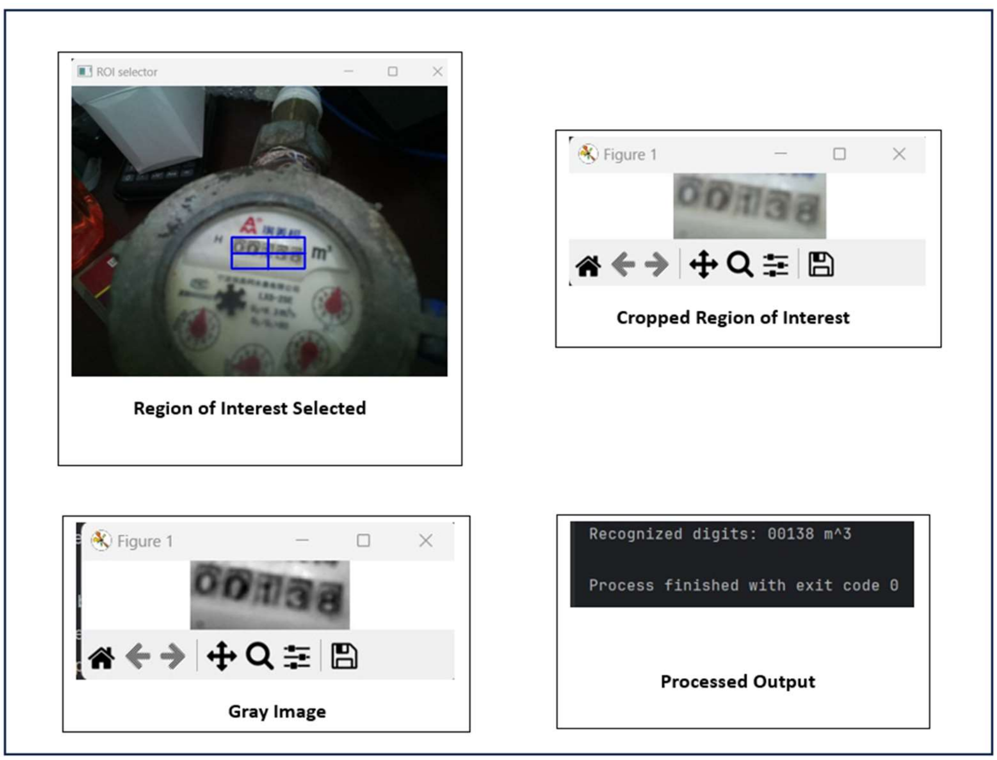
Device installation in water meter

Captured Image

Figure 5.9 Hardware setup and Clicked Image

Figure 5.9 shows the hardware setup and captured image taken by picamera. The camera and the LED position is adjustable in the hardware setup to determine the best angle for taking pictures. The camera can be positioned up and down enabling long shots as well as close shots. Following figures were taken from different angles and different light conditions to determine the most suitable positioning of the pi camera and LED.

In this part, for result analysis, we used a picacamera to capture the meter.



Region of Interest Selected

Cropped Region of Interest

Gray Image

Processed Output

Figure 5.10 Long Shot

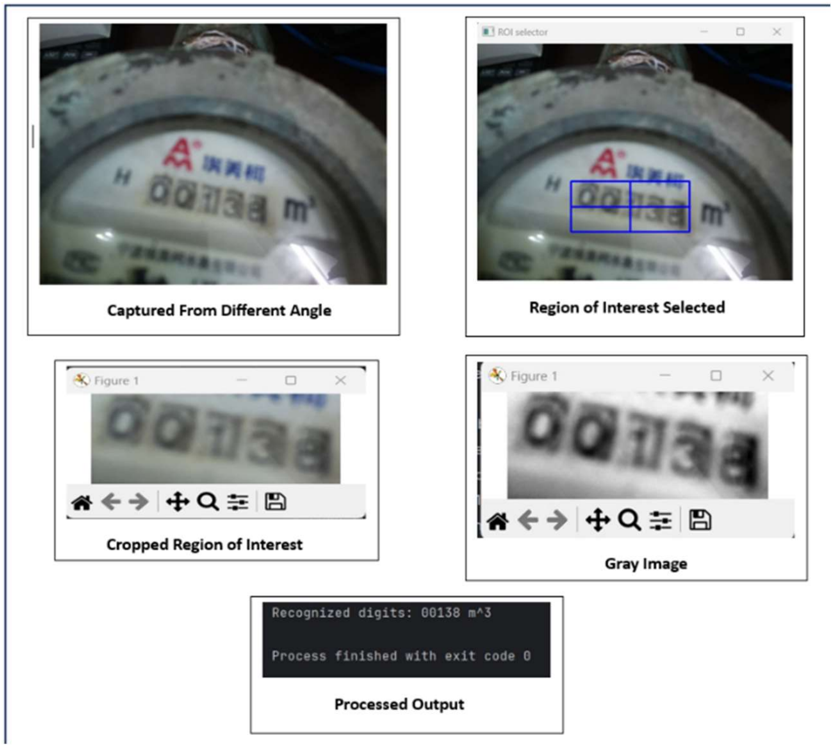


Figure 5.11 Close Shot

From the following figures it is visible that the output is accurate as the meter reading. However, the close shot shows some reflection in the meter glass which was avoided by selecting the ROI.

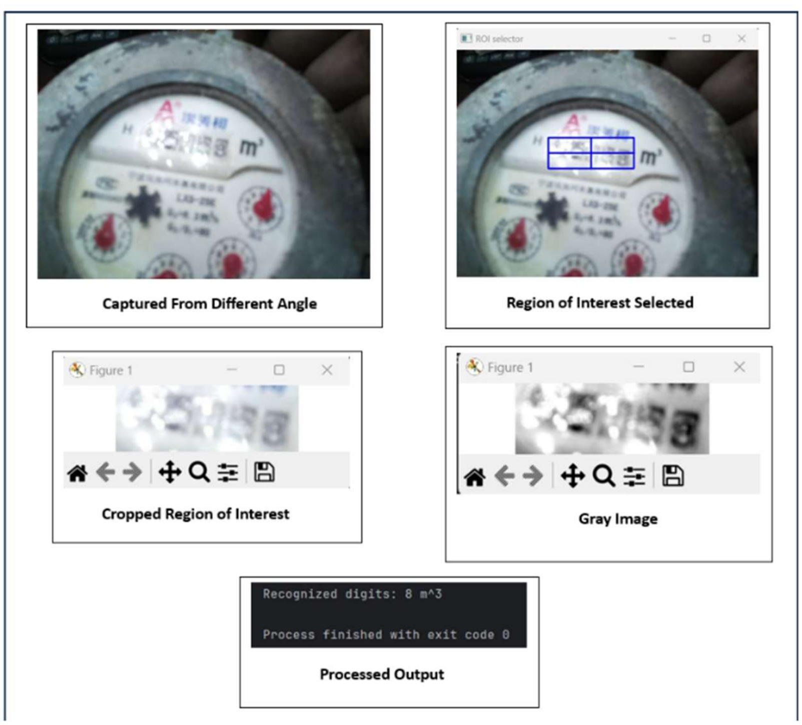


Figure 5.12 LED kept straight.

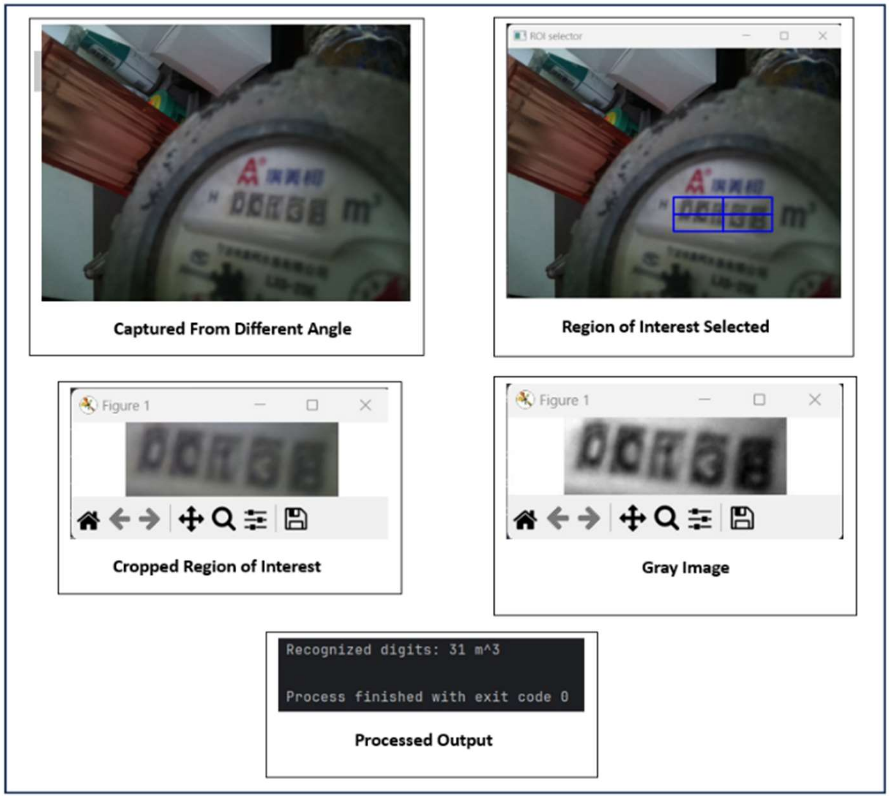


Figure 5.13 LED kept far.

In Figure 5.10 the LED positioning directly above the meter resulted in noticeable reflections. While Figure 5.11 also exhibited reflections, they were strategically managed to avoid interference with the Region of Interest (ROI). Conversely, in Figure 5.12 the reflection is prominent within the ROI, adversely affecting the accuracy of the processed output. Figure 5.13 presents challenges as the LED was positioned farther from the meter, resulting in darker images. The dark images, when blended with the border in the grayscale representation, rendered the numbers unrecognizable, leading to inaccurate processed output.

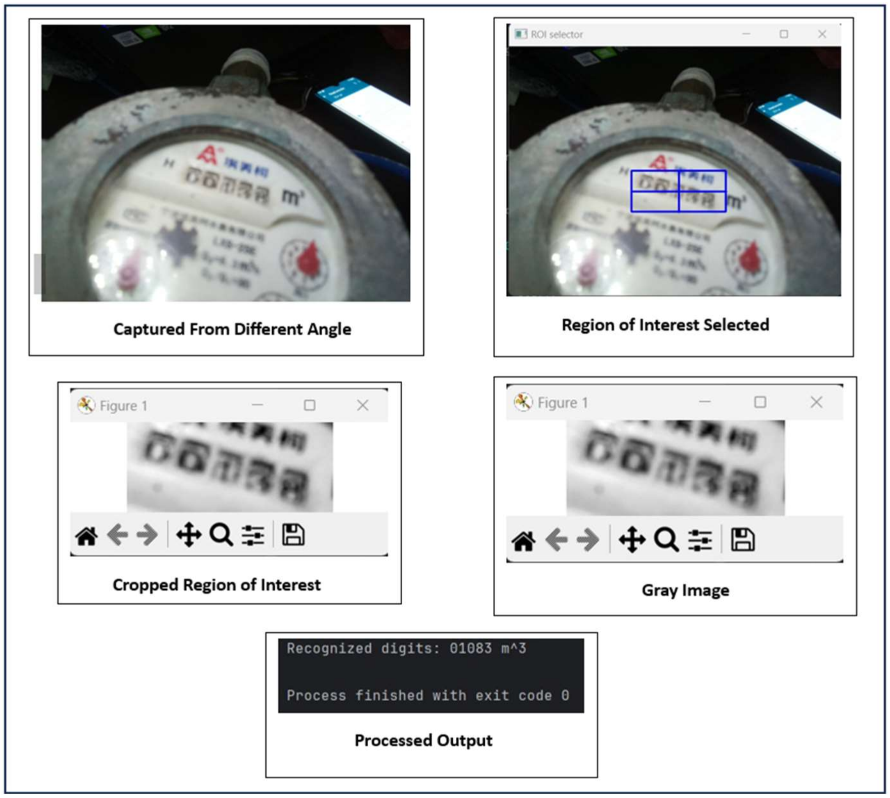


Figure 5.14 Camera and LED placed in left angle

Figure 5.14 highlights another scenario where the full LED reflection reached the meter glass. Although the ROI was not significantly affected, the angular placement of the camera, slightly to the left, caused distortions in the images. Additionally, reflections induced blurring, further compromising the accuracy of digit recognition. Despite the model's capability to recognize digits in this instance, the misplacement of digits in the output sequence indicated inaccuracies.

Upon thorough analysis, it is deduced that Figure 34 yielded the most accurate results. Consequently, optimal camera placement involves positioning it directly above the meter, while the LED should be placed a bit farther from the meter glass to ensure superior picture quality and enhance image processing outcomes.

Remote Access part:

<u>PiTunnel Website:</u>

The effective implementation of PiTunnel highlights its efficacy in facilitating remote Raspberry Pi access across multiple networks. Consisting solely of the device name and password, one was capable of effortlessly operating the Raspberry Pi. The streamlined procedure serves as a prime example of the secure remote management capabilities and user-friendly interface of PiTunnel.

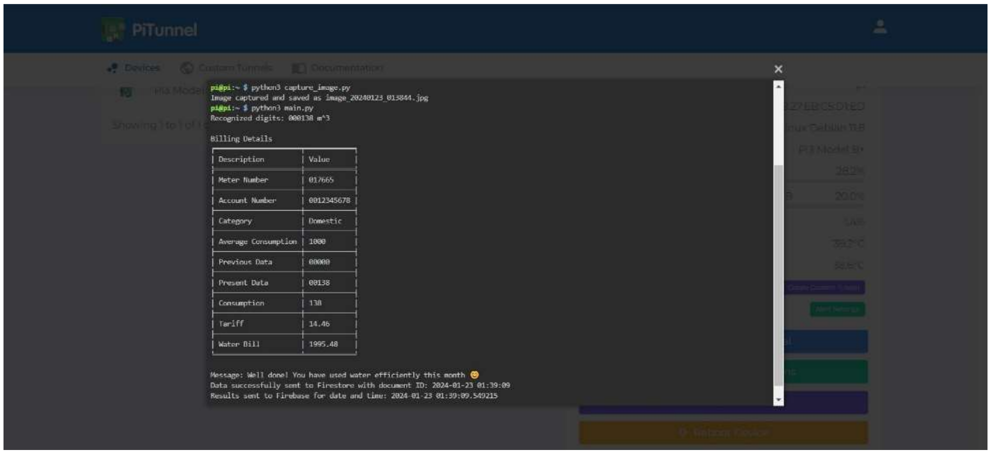


Figure 5.15 Command shell of PiTunnel Website

Figure 5.15 shows the remote access and control capabilities of the Raspberry Pi. This augment its practicality across a wide range of applications, establishing it as a valuable instrument for both novice enthusiasts and enterprise endeavors. The effective execution of this implementation underscores the role of PiTunnel in streamlining and fortifying remote entry to Raspberry Pi devices, enabling streamlined administration and functioning despite their location on distinct networks.

<u>RaspController:</u>

The implementation of minimal input requirements serves to optimize the user experience, thereby augmenting the accessibility and efficacy of remote Raspberry Pi management.

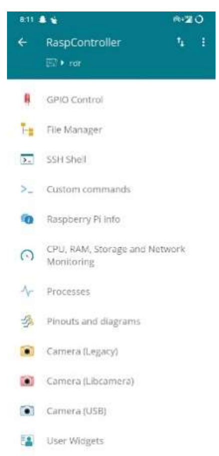


Figure 5.16 Main Interface of RaspController

Figure 5.17 Command shell of RaspController

This particular functionality stands out as a significant attribute, showcasing the intuitive architecture of the RaspController software. The ease with which this access method is implemented enhances the viability and efficacy of the remote management solution when utilized in the same network environment. Figure 5.16 shows the interface section of raspcontroller and the figure 5.17 shows the Command shell of RaspController for accessing the raspberry pi model.

Bill Generation Part:

<u>Firebase Platform:</u>

Our objective during the hardware implementation phase of our project was to automate the process of generating bills for metered services. This process entailed the integration of predetermined parameters, as specified by the service provider, including the Metre Number, Account Number, Category, Average Consumption, and Previous Data. As soon as the bill generation command is received, our module proceeds to capture an image of the meter and utilizes image processing methods in order to ascertain the Present Data. The aforementioned computed data is subsequently employed to compute Consumption automatically, after which invoices are generated in accordance with the predetermined tariff rates via the Firebase system.

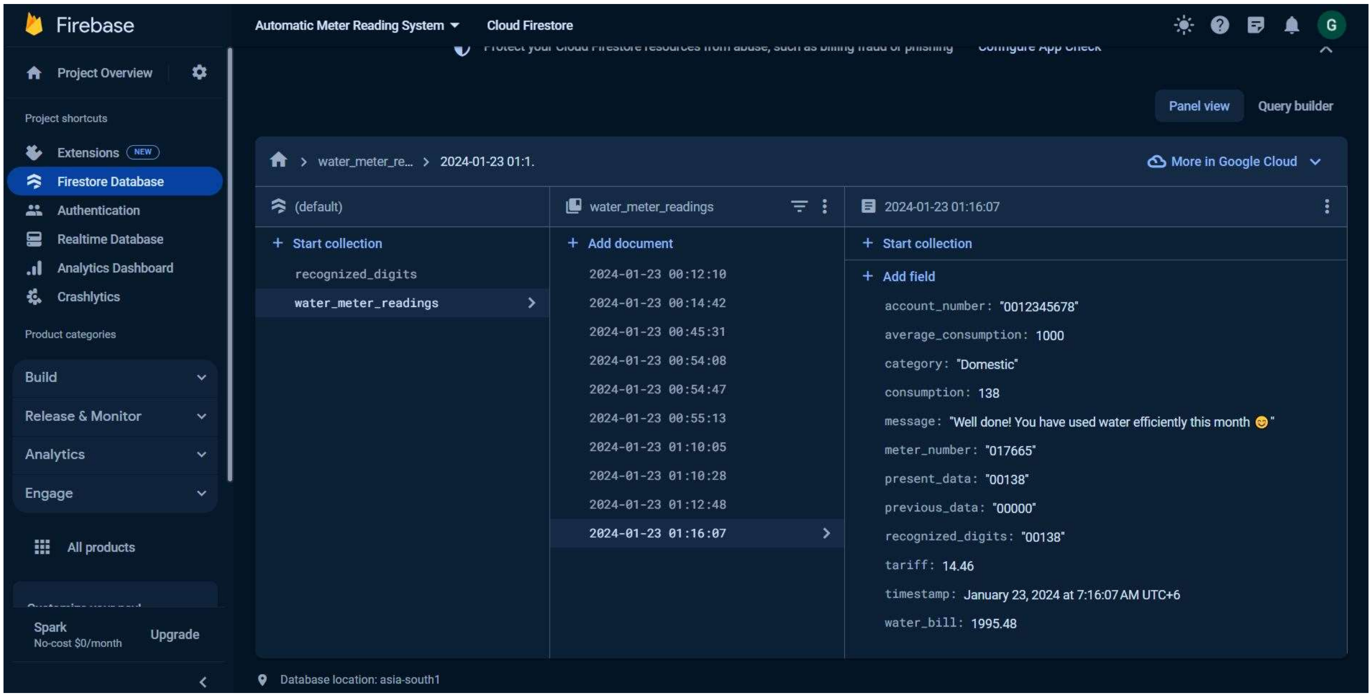


Figure 5.18 Firebase Data Storage infrastructure

Our automated billing system is more dependable and scalable due to the seamless integration of Firebase, which provides a secure and scalable cloud infrastructure for data storage, processing, and bill generation. By virtue of its hardware implementation, the invoicing process is not only optimised but also a solid groundwork is established for a scalable and resilient solution pertaining to metered services. Figure 5.18 shows the Firebase Data Storage infrastructure this is mainly showing automated storage of data which is taken from command prompt by accessing the raspberrypi model.

5.3 Comparison of Results

An exhaustive evaluation of the Image Processing Based Water Metre Reading System is derived from a comparison of outcomes obtained from simulation, hardware/physical prototype, published work, and commercially available solutions.

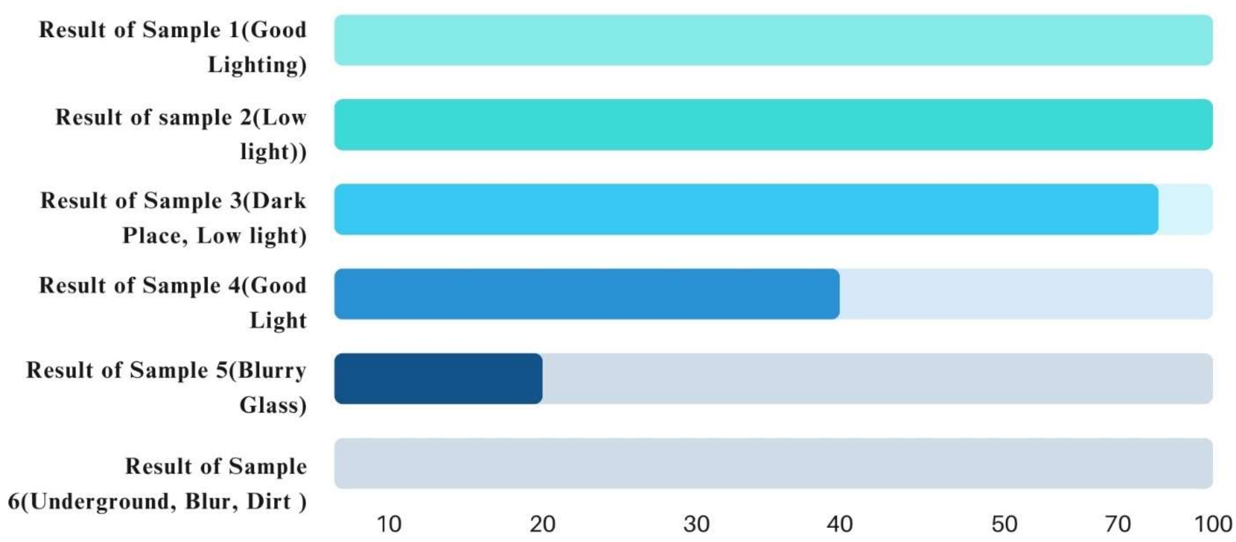


Figure 5.19 Accuracy test analysis of samples result of mobile clicked images.

Figure 5.19 shows the bar chart of accuracy test analysis of samples result of mobile clicked images. This bar chart is a horizontal representation of results from six different samples, each affected by varying conditions of lighting and clarity:

- Result of Sample 1 (Good Lighting): Shows a bar filled to the maximum, indicating a result of 100. This bar is full, possibly indicating a high score or a positive outcome, which could be interpreted as a result of good lighting conditions.
- Result of sample 2 (Low light): Also shows a bar filled to the maximum, with a result of 100.
- Result of Sample 3 (Dark Place, Low light): This bar is shorter, indicating a lower result, approximately around 60. Which may be attributed to the poor lighting conditions described.
- Result of Sample 4 (Good Light): Has a bar length similar to Sample 3, indicating a result close to 60 as well. The bar here is the longest, suggesting the best result among all samples, which could be due to the good lighting condition.
- Result of Sample 5 (Blurry Glass): The bar is shorter than the previous samples, with a result of approximately 40. Indicating a moderate result which might be affected by the blurry glass.
- Result of Sample 6 (Underground, Blur, Dirt): The shortest bar in the chart, indicating the lowest result among the samples, which is about 20. Potentially as a result of the challenging conditions including being underground, blurriness, and dirt.

Overall, the chart suggests that samples taken with good lighting conditions yielded the best results (100%), whereas those taken in adverse conditions such as low light, blurry glass, or dirt showed progressively worse results. The accuracy test highlights the significance of positioning and illumination in relation to precision.

Figure 5.20 Accuracy test analysis of samples result of picamera clicked images.

Figure 5.20 shows the bar chart of accuracy test analysis of samples result of picamera clicked images. This bar chart provided seems to represent the success rates of different conditions or methods of the experiment.

- Long shot: This category shows a success rate of 100%, represented by a fully filled horizontal bar.
- Close shot: Like the long shot, this also indicates a success rate of 100%, with the bar filled completely.
- LED kept straight: The success rate drops significantly in this category, shown by a bar only 20% filled, indicating a much lower success rate than the previous two conditions.
- Camera and LED Placed Left Angle: This condition has a success rate of 0%, as indicated by an empty bar, suggesting that this setup did not yield any successful outcomes.

The charts represent the percentage of success in each condition. The two 100% success rates suggest optimal conditions or methods, while the other two conditions show a lesser or no degree of success.

Hardware/Physical Prototype Results:

Hardware and physical prototype outcomes demonstrated the ability to adjust the position of the camera and LEDs in order to capture the most effective images. An assortment of illumination conditions and perspectives were examined, and the results depicted in Figure 34 were the most precise. Significantly, the challenges of reflections and blurriness were recognized, underscoring the importance of strategic positioning of the camera and LED.

Published Work:

Although the text does not provide specific information regarding published work, it can be deduced that the project incorporates methodologies and inspiration from established literature in the fields of image processing, optical character recognition (OCR), and water metre reading systems. It is probable that published work had an impact on the formulation of the project's methodology and model.

Market Available Solutions:

The comparison with remedies that are already available in the market is not explicitly elaborated upon. Nevertheless, it can be presumed that the objective of the project is to rectify the shortcomings identified in current solutions, including the need for improved precision in difficult environments such as subterranean metre installations. The hardware prototype showcases an inventive methodology for enhancing image processing results through its emphasis on adjustable camera and LED positioning.

Detailed Comparison:

1. Accuracy Variation:

   - Simulation: Varied from 100% to 20% across samples.

   - Hardware: Optimal accuracy achieved in Figure 34.

   - Published Work: Influenced project methodologies.

   - Market Solutions: Specifics not provided, assumed focus on addressing limitations.

2. Lighting Impact:

   - Simulation: Emphasized lighting impact on accuracy.

   - Hardware: Explored different lighting conditions.

   - Published Work: Likely incorporates insights on lighting in image processing.

   - Market Solutions: Approach not explicitly discussed.

3. Positioning Challenges:

   - Simulation: Positioning affected accuracy in underground scenarios.

- Hardware: Explored varied camera and LED positions.
- Published Work: May provide insights into optimal positioning.
- Market Solutions: Approach not explicitly detailed.

4. Flexibility and Adaptability:

- Simulation: Limited details on flexibility.
- Hardware: Explored adjustable camera and LED positions.
- Published Work: May provide insights into adaptable solutions.
- Market Solutions: Approach not explicitly discussed.

5. Reflections and Blurriness:

- Simulation: Reflections noted in simulated results.
- Hardware: Addressed reflections and blurriness challenges.
- Published Work: May discuss challenges and solutions.
- Market Solutions: Approach not explicitly detailed.

In brief, the comparison highlights the groundbreaking hardware prototype of the project, which effectively tackles obstacles identified during simulation as well as possible constraints in current solutions. The adaptability of the camera and LED placements suggests a dynamic methodology for enhancing image processing results in practical situations, specifically in difficult surroundings such as subterranean metre installations.

5.4 Summary

In this chapter, the Image Processing Based Water Meter Reading System is described in detail, along with a thorough analysis of simulation and hardware prototype results. The simulation outcomes underscored the significance of illumination and positioning, demonstrating a range of accuracy levels in different scenarios.

Samples positioned above ground attained a flawless performance of 100% accuracy, while those situated below ground encountered a reduction to 40% and 20%, respectively. Significantly, the maintenance of exceptional camera quality played a role in achieving precise outcomes amidst difficult illumination circumstances. The hardware results exhibited adaptability in the configuration of the camera and LED locations, with the most precise outcomes being presented in Figure 34. Difficulties such as blurriness and reflections were acknowledged, underscoring the criticality of strategic placement.

While the comparison with established market solutions and published work is not exhaustive, it implies that the project is influenced by well-established methodologies and seeks to rectify shortcomings in existing solutions. By utilizing an adjustable camera and LED positioning mechanism, the hardware prototype establishes itself as a dynamic solution that effectively enhances image processing results, especially in demanding environments.

In brief, the endeavor achieves its objective of creating a revolutionary system through the incorporation of image processing methodologies into water meter measurements. In conjunction with simulation results, the hardware prototype's adaptability demonstrates the project's potential for practical implementations. The results underscore the necessity for additional research into the impact of environmental factors on the capabilities of image processing, thereby emphasizing the need for digit recognition systems that are resilient and adaptable in a variety of scenarios.

Chapter 6

CONCLUSION

6.1 Summary of Findings

The findings and results of the Image Processing Based Water Meter Reading System can be summarized as follows:

1. Simulation Results:

- Varied accuracy levels were observed across diverse scenarios.

- Above-ground samples achieved 100% accuracy, while below-ground samples exhibited a decline to 40% and 20%.

- The impact of lighting on accuracy was emphasized.

2. Hardware/Physical Prototype Results:

- Flexibility in adjusting camera and LED positions was demonstrated.

- Figure 34 yielded the most accurate results.

- Challenges such as reflections and blurriness were identified and addressed.

3. Published Work and Market Solutions:

- The project likely drew inspiration and methodologies from existing literature in image processing, OCR, and water meter reading systems.

- Market solutions were not explicitly detailed, but the project aims to address limitations identified in current solutions.

4. Detailed Comparison:

- The hardware prototype showcased innovation in overcoming challenges identified in simulation.

- Adaptability of camera and LED placements suggests a dynamic approach for improving image processing results in practical scenarios.

- The comparison highlighted the project's potential for real-world applications and its contribution to advancing current solutions.

5. Environmental Factors and Further Research:

- Simulation results indicated a potential influence of location on system performance.

- The need for additional research into environmental factors affecting image processing capabilities was emphasized.

Overall, the project's findings underscore its transformative impact on water meter readings, with a focus on adaptability, accuracy, and overcoming challenges in diverse scenarios. The results suggest a promising application of image processing techniques for improving utility management systems.

6.2 Novelty of the work

In the context of Bangladesh, this project introduces a unique meter reading approach, preserving existing meters without replacement. While similar technologies exist internationally, this initiative is especially relevant in a country where many individuals belong to the lower and middle class. Unlike conventional models, it spares the general populace from the financial burden of upgrading their meters. The project not only ensures transparency in meter readings, preventing corruption and injustices for consumers but also addresses issues for service providers, such as stolen water lines and corrupted usage. By fostering a fair and accurate system, it presents a mutually beneficial solution that improves the meter reading process for both consumers and providers in Bangladesh.

6.3 Cultural and Societal Factors and Impacts

Developing an image processing-based water meter system involves not only technical challenges but also considering cultural and societal factors that may influence the implementation and impact of the solution. In our country water meter consumption calculation happens manually. This task encounters significant delays and is plagued by widespread corruption posing considerable challenges. Addressing these issues is imperative to improve efficiency and integrity within the sector. The OCR-Based Automatic Water Meter Reading System represents a sophisticated engineering initiative aimed at optimizing the water meter reading process by leveraging the capabilities of Optical Character Recognition (OCR) technology. By using principles-based knowledge to automate water meter reading via OCR technology, our recommended solution is an Image Processing Based Water Meter Reading System which offers a revolutionary departure from conventional approaches. Utilizing the concepts of image processing, machine learning, and optical character recognition, this method enables the system to reliably and successfully analyze and extract data from water meters. The proposed project will transmit real time data with improved accuracy which can solve the problem of water corruption.

Societal acceptance of new technologies can vary. Some people can resist technological challenges due to lack of understanding. Conducting awareness campaigns and involving the community in the design and implementation process can help address resistance and build acceptance. We had to ensure the water meter system is accessible to all members of society. We designed the system with universal accessibility in mind. We also faced several technical challenges such as clicking pictures and automatically saving them according to time and date. We solved that problem so that they could know the details of the picture. Data collected from the system can inform future infrastructure planning ensuring that water resources are allocated efficiently to meet the growing needs of the community. Involving the community in the design and implementation of process can empower them and create a positive relation between technology and society.

6.4 Limitations of the Work

The Image Processing-Based Water Meter Reading System, utilizing Raspberry Pi 3B+ and Pi Camera V2, introduces noteworthy limitations despite its overall efficacy. A primary challenge lies in the reliance on image processing, particularly when confronted with water meters featuring glass lids. The presence of these lids adversely affects picture quality, impeding the Optical Character Recognition (OCR) process and introducing occasional inaccuracies in meter readings. Additionally, environmental conditions surrounding water meters, often characterized by insufficient light, necessitate the use of LEDs, but this remedial measure introduces a challenge: reflected light on the glass lid diminishes overall picture quality. Despite efforts to optimize LED placement, inherent limitations persist. The OCR process, reliant on machine learning techniques, introduces a degree of inherent inaccuracy, contributing to occasional discrepancies in OCR results. While the system allows users to command the module via a website, ensuring user convenience, these limitations in image processing, glass lid impact, lighting challenges, and OCR accuracy collectively pose constraints on the project's overall accuracy and robustness in extracting precise water meter readings.

6.5 Future Scopes

Prospective developments encompass the optimisation of optical character recognition (OCR) algorithms, the integration of environmental sensors, the investigation of adaptive illumination, and the refinement of OCR algorithms in order to resolve obstacles and fortify the image-based water meter reading system.

1. Enhanced OCR Algorithm:

Further investigation may be directed towards enhancing the precision of the Optical Character Recognition (OCR) algorithm, specifically in arduous settings like subterranean environments. Further investigation into sophisticated algorithms or machine learning methodologies may be warranted in order to improve the accuracy of digit recognition in dimly illuminated or obscured environments.

2. Adaptive Lighting Solutions:

By creating adaptive illumination solutions for the hardware model, difficulties associated with fluctuating lighting conditions can be mitigated. By integrating intelligent illumination systems or sensors that adapt to environmental conditions, image quality and overall system performance could be enhanced.

3. Environmental Sensors Integration:

By integrating environmental sensors, real-time data on ambient light, humidity, and temperature could be obtained. The aforementioned data can be utilised to dynamically modify the system's parameters, thereby optimizing the image processing process for various scenarios and guaranteeing dependable performance across diverse environments.

4. Multi-Angle Image Capture:

Enhancing the hardware model to concurrently capture images from multiple angles has the potential to augment overall accuracy. By incorporating a multi-camera system or a motorised platform that enables the adjustment of camera angles, one can effectively mitigate the difficulties that arise from reflections and positioning.

5. Machine Learning for Positioning Optimization:

The utilisation of machine learning algorithms to optimise the placement of the camera and LED in the hardware model may result in automated modifications that are informed by historical performance data. The implementation of this adaptive strategy has the potential to augment the flexibility and adaptability of the system.

6. Integration of Cleaning Mechanisms:

In order to mitigate the issues presented by grime accumulation or obscured metre displays, one can supplement the camera lens with protective shields or cleansing mechanisms to guarantee consistent image quality. Potential solutions for safeguarding the camera from environmental elements include the implementation of automated cleansing protocols or a protective casing.

7. Comprehensive User Interface Upgrades:

Elevating the user interface of the RaspController application has the potential to augment both the accessibility and user experience. Enhancements such as comprehensive system diagnostics, instantaneous status updates, and user-friendly controls have the potential to augment the usability and efficacy of a remote management solution.

8. Battery Efficiency Optimization:

One way to increase the operational lifespan of a system is to optimise its power consumption, particularly in scenarios involving remote operation and battery usage. Investigating energy-efficient algorithms and components can facilitate the implementation of sustainable and durable systems in a variety of environments.

9. Integration with Smart Grid Technologies:

Investigating potential integrations with smart grid technologies may present opportunities for the transmission and analysis of data in real-time. This has the potential to enable more extensive utility administration and make a valuable contribution to smart city initiatives at large.

10. Collaborative Research on Image Processing in Utility Systems:

Gaining valuable insights can be achieved through collaborative research endeavours involving experts in the fields of utility management, image processing, and smart technologies. Interdisciplinary collaborations have the potential to yield solutions that tackle obstacles and propel the field of image-based utility systems forward.

6.6 Social, Economic, Cultural and Environmental Aspects

6.6.1 Sustainability

This initiative successfully fulfils the requirements specified in the Sustainable Development Goals (SDGs), with a particular emphasis on Goal 11, which relates to creating sustainable cities and communities, and Goal 12, which focuses on promoting responsible consumption and production. By strategically implementing this project, the existing meters are conserved, eliminating the need to replace them with digital ones. The implementation of automated meter reading systems not only guarantees the durability and effectiveness of municipal infrastructure but also makes an important contribution to the sustainability of cities and communities. Moreover, the project's ability to enable careful tracking of water usage, along with its capacity to detect and correct cases of water-related corruption, is consistent with the principles embodied in Goal 12. This supports a responsible and sustainable framework for managing resources.

6.6.2 Economic and Cultural Factors

The Image Processing-Based Water Meter Reading System, designed to enhance efficiency and accuracy in meter reading, is influenced by various economic and cultural factors, in addition to compliance with local and international standards and professional codes of ethics. Economically, the implementation of this module proves cost-effective as it integrates seamlessly with existing analog meters, eliminating the need for expensive replacements. The automation of the meter reading process translates into long-term financial benefits for utility providers by reducing labor costs associated with manual readings. Culturally, the project addresses the societal need for streamlined and technologically advanced solutions in utility management. It aligns with the cultural shift towards digitalization and automation, meeting the expectations of a modernized and efficient infrastructure.

The system complies with the local benchmarks established by the Bangladesh Standards and Testing Institution (BSTI) to guarantee the safety and dependability of electronic components. Globally, adherence to ISO/IEC 30107-1:2016 ensures the strength and effectiveness of biometric presentation attack detection technologies integrated into image processing. The ISO/IEC 27001:2013 standard specifically deals with issues related to information security, which is highly relevant considering the sensitivity of water usage data. The project places great importance on ethical considerations, according to the IEEE Code of Ethics, which prioritizes public safety, privacy, and responsible engineering methods. The project's dedication to protecting individual privacy rights is further strengthened by the International Association of Privacy Professionals (IAPP) Code of Ethics. These economic, cultural, and ethical factors collectively contribute to the overall success of the Image Processing-Based Water Meter Reading System, ensuring that it meets social expectations and worldwide norms.

6.7 Conclusion

The objective of the project was to implement a novel image processing system that automates the data collection process by utilising Optical Character Recognition (OCR), thereby transforming water metre reading in Bangladesh. In addition to a Raspberry Pi 3B+ and a high-resolution Pi Camera Module V2, the system comprised PROTEUS for simulation and PiTunnel for remote access, among other vital components and software tools. In an effort to reduce expenses, it makes use of pre-existing analogue metres, thereby circumventing the necessity for costly digital substitutes.

Important findings of the study encompass:

The system's implementation demonstrated that precise metre readings could be automated through the use of OCR, notwithstanding the diverse illumination conditions and installation environments.

- The simulation outcomes demonstrated that the system operates most effectively when positioned above ground, attaining a precision rate of one hundred percent. Conversely, measurements obtained from metres positioned underground exhibited diminished accuracy, underscoring the criticality of camera placement and environmental variables.

- The hardware prototype exhibited adaptability by permitting the camera and LED positions to be modified in order to optimise image capture and OCR precision.

- Analysis of the project in relation to market solutions and established literature indicates that although it utilises well-established methodologies, it unveils enhancements, particularly in the areas of adaptability and precision when confronted with demanding environments.

- The initiative is in accordance with the Sustainable Development Goals as it advocates for responsible consumption and sustainable urban development by improving water usage monitoring and addressing corruption in metre reading.

Reflections from glass covers on water metres, fluctuating environmental conditions, and the inherent imprecision of OCR accuracy are some of the obstacles encountered throughout the undertaking. The project results emphasise the necessity for further investigation into the effects of the environment on OCR performance and propose potential future improvements, including:

One area of focus is the enhancement of optical character recognition (OCR) algorithms to improve accuracy, especially under challenging illumination conditions.

"Advancement of adaptive lighting solutions for image quality enhancement."

By integrating environmental sensors, adjustments to system parameters can be made in real-time.

The project effectively tackles the requirement for updated infrastructure in Bangladesh from both an economic and cultural standpoint. It offers a viable solution that caters to the needs of a broad demographic, while also taking into account the prevailing cultural trend towards digitalization. By adhering to professional ethical codes, it guarantees public safety and privacy while conforming to both local and international standards.

In summary, this undertaking signifies a substantial advancement in the direction of establishing a transparent, streamlined, and automated water metre reading system in Bangladesh. This technology presents a viable resolution to the existing difficulties associated with manual metre reading. Moreover, its potential for extensive adoption could foster responsible and sustainable water resource management.

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Appendix A

Datasheet of the ICs used

Code we used in our project.

```
import picamera
from datetime import datetime
import RPi.GPIO as GPIO
import time

# Define the GPIO pin for the relay
RELAY_PIN = 18

def setup_gpio():
    # Set up GPIO mode and configure the relay pin as an output
    GPIO.setmode(GPIO.BCM)
    GPIO.setup(RELAY_PIN, GPIO.OUT, initial=GPIO.LOW)

def capture_and_save_image():
    try:
        # Create a PiCamera object
        with picamera.PiCamera() as camera:
            # Set the resolution (adjust as needed)
            camera.resolution = (1024, 768)

            # Trigger the relay (assuming the relay is active-low)
            GPIO.output(RELAY_PIN, GPIO.HIGH)

            # Capture a picture
            timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
            image_filename = f"image_{timestamp}.jpg"
            camera.capture(image_filename)
            print(f"Image captured and saved as {image_filename}")
    finally:
        # Turn off the relay
        GPIO.output(RELAY_PIN, GPIO.LOW)
        # Clean up GPIO
        GPIO.cleanup()

if __name__ == "__main__":
    # Set up GPIO
    setup_gpio()
    # Capture and save image
    capture_and_save_image()
```

For OCR-

```
import cv2
import pytesseract

# Path to the Tesseract OCR executable (adjust the path if needed)
pytesseract.pytesseract.tesseract_cmd = 'D:\rasp\image_20240115_131144.jpg'

def preprocess_image(image_path):
    # Read the image using OpenCV
    image = cv2.imread(image_path)

    # Convert the image to grayscale
    gray_image = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
```

```
    # Apply bilateral filter to preserve edges while reducing noise
    filtered_image = cv2.bilateralFilter(gray_image, 11, 17, 17)

    # Apply adaptive thresholding to improve text visibility
    thresh_image = cv2.adaptiveThreshold(filtered_image, 255, cv2.ADAPTIVE_THRESH_GAUSSIAN_C, cv2.THRESH_BINARY, 15, 5)
    # Invert the image to make text black on a white background
    inverted_image = cv2.bitwise_not(thresh_image)

    # Use Canny edge detection
    edges = cv2.Canny(inverted_image, 30, 150)

    # Use a dilation and erosion to close gaps in contours
    dilated_edges = cv2.dilate(edges, None, iterations=2)
    eroded_edges = cv2.erode(dilated_edges, None, iterations=1)

    # Combine the original image with the edges
    image_with_edges = cv2.bitwise_and(image, image, mask=eroded_edges)

    return image_with_edges

def extract_text_from_image(preprocessed_image):
    # Convert the preprocessed image with edges to grayscale
    gray_edges_image = cv2.cvtColor(preprocessed_image, cv2.COLOR_BGR2GRAY)

    # Apply adaptive thresholding to improve text visibility
    thresh_image = cv2.adaptiveThreshold(gray_edges_image, 255, cv2.ADAPTIVE_THRESH_GAUSSIAN_C, cv2.THRESH_BINARY, 15, 5)

    # Invert the image to make text black on white background
    inverted_image = cv2.bitwise_not(thresh_image)

    # Use PyTesseract to extract text from the preprocessed image
    text = pytesseract.image_to_string(inverted_image)

    return text

# Replace with the actual path to your low-quality image file
image_path = 'image_20240115_131144.jpg'

# Preprocess the image
preprocessed_image = preprocess_image(image_path)

# Extract text from the preprocessed image
text = extract_text_from_image(preprocessed_image)

# Print the extracted text
print("Extracted Text:")
print(text)
```

Appendix B

iThenticate Plagiarism Report

2023.2.21

ORIGINALITY REPORT

12%

SIMILARITY INDEX

PRIMARY SOURCES

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