**Automatic Electricity Meter Reading Based on Image Processing**

Final Year Project

PROPOSAL

****

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**Submitted by (BSCS-S24-012)**

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Abstract

Electricity meter reading is a critical yet time-consuming task that often involves manual data collection. The current manual process poses several challenges, including human errors, inefficiency, and the potential for data tampering. Moreover, it becomes increasingly challenging in densely populated areas or locations with difficult accessibility. This project addresses the need for a more efficient and accurate method for electricity meter reading. The significance of automating this process lies in streamlining operations, reducing errors, and ensuring fair billing for consumers. By leveraging image processing techniques, we aim to develop a solution that not only enhances the reliability of meter readings but also contributes to the overall modernization of utility management systems.

Our proposed solution involves the utilization of advanced image processing technologies to automate electricity meter reading. We plan to employ state-of-the-art algorithms and machine learning models such as RCNN (Region-based Convolutional Neural Networks), YOLO V4 (You Only Look Once version 4), Fast OCR (Optical Character Recognition), and techniques tailored for handling Small Objects in images. These algorithms will enable us to analyze images of electricity meters and extract accurate readings. The project will utilize image recognition and pattern matching techniques to identify and interpret the meter digits, overcoming challenges such as varying lighting conditions and meter designs. By integrating these technologies, we aim to create a robust system capable of handling diverse meter types and delivering real-time, accurate readings. This not only improves operational efficiency for utility providers but also ensures a fair and transparent billing process for consumers, contributing to the advancement of smart utility management systems.

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# Introduction

Managing electricity is super important nowadays. But checking meters by hand can be really tricky, especially in busy areas or places that are hard to reach. Taking meter readings manually not only takes a lot of time but can also lead to mistakes or even someone tampering with the data. So, we're working on a project to change all that!

We're using fancy technology called image processing to make meter reading easier and more accurate. By using smart algorithms like CNN, RCNN and YOLO V4, we can analyse pictures of meters and get the readings just right. This means fewer mistakes and faster billing for you. Plus, we're making sure our system can handle all kinds of meters and lighting conditions, so it works wherever you are. It's not just about helping the utility companies work better; it's also about making sure you get fair and transparent bills.

|  |  |  |  |
| --- | --- | --- | --- |
| **Final Year Project** | CLO | PROBLEMS | **SOLUTIONS our FYP** |
| CLO1 | Analyze the given problem to propose a computing based solution. | Begin by understanding the challenges involved in manual meter reading and the potential benefits of automating the process. |
| CLO2 | Design and develop computing solutions to the complex computing problems. | Develop algorithms for image segmentation, character recognition, and error correction to handle complex scenarios. |
| CLO3 | Demonstrate the ability to use modern tool to solve the given problem. | Utilize libraries and frameworks such as OpenCV, TensorFlow, or PyTorch for image processing and machine learning. |
| CLO4 | Demonstrate the ability to work affectively as an individual and a team member. | Collaborate with team members to divide tasks based on expertise and ensure smooth development. |
| CLO5 | Understand the significance of broader aspect of innovation and development | Stay updated on emerging technologies and research to continually improve and innovate the solution. |
| CLO6 | Demonstrate effective skills in verbal and written communication during presentations, discussions and reports. | Engage in discussions to gather feedback, address concerns, and iterate on the solution effectively. |

# Problem Description

## Primary Scope

The primary scope of the project, "Automatic Electricity Meter Reading Based on Image Processing," revolves around the development of an advanced system to automate the electricity meter reading process. The project aims to alleviate the challenges associated with manual readings, including the potential for human errors, operational inefficiencies, and data tampering. The central objective is to leverage image processing technologies for improved accuracy, reliability, and transparency in electricity meter readings.

Key features of the system include the implementation of sophisticated algorithms for image recognition and pattern matching, ensuring adaptability to various meter designs and effective performance under diverse lighting conditions. The primary focus is on creating a fault-tolerant solution to minimize data collection errors, ultimately leading to fair and precise billing for consumers. Through the automation of meter readings, the project strives to streamline utility management operations, enabling real-time data analysis and enhancing overall operational efficiency.

The primary scope extends to the system's flexibility in accommodating both (digital and analog) types of electricity meters, reflecting a comprehensive approach to modernizing utility infrastructure. By addressing the 'What' and 'Why' of the project within this scope, the goal is to establish a foundation for an innovative solution that not only mitigates the limitations of manual readings but also aligns with broader objectives in advancing smart technologies within utility management.

## Final Deliverable of the Project and Beneficiaries

The final deliverable of this project will be a mobile app comprising both frontend and backend components. The beneficiaries of this mobile application are the users who rely on daily common task such as bill calculations, accurate meter reading through image analysis.

## Objectives

1. To automate electricity meter reading, utilize image processing techniques with OpenCV and Scikit-Image.
2. To achieve precise readings, employ advanced algorithms like RCNN and YOLO V4, supported by NumPy and SciPy.
3. To ensure fair billing, accurately identify and interpret meter digits using Pillow/PIL and Mahotas.
4. To enable real-time readings in diverse settings, develop a robust system integrating SimpleITK and Pgmagick.

## Novelty

“There is no similar FYP already approved in BULC.”

# Methodology

To develop an automated electric meter reading system utilizing image processing techniques, we aim to follow a comprehensive approach comprising several stages.

1. Data Acquisition and Preprocessing:

Collect a diverse dataset of electric meter images encompassing various lighting conditions, meter types, and digit Styles. Preprocess the images by applying techniques like noise reduction, resizing, and grayscale conversion.

2. Meter Identification and Segmentation:

Develop an image processing algorithm to identify the meter region within the captured image.

3. Digit Recognition:

Choose a suitable AI model, such as Convolutional Neural Networks (CNNs), for recognizing individual digits within the segmented region. Train the chosen model using the preprocessed dataset, ensuring high accuracy in digit recognition.

4. System Integration and User Interface:

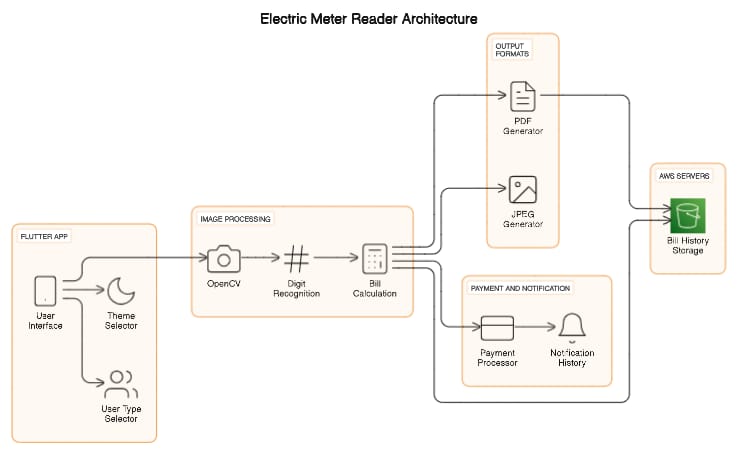
Integrate the developed components - image acquisition, preprocessing, meter identification, digit recognition - into a cohesive system. Design a user-friendly interface for capturing meter images, displaying recognized readings, and potentially managing historical data.

5. Testing and Evaluation:

Test the system's performance on a separate test dataset to assess accuracy under diverse Conditions. Evaluate the system's effectiveness compared to traditional meter reading methods, considering factors like accuracy, efficiency, and user experience.

6. Deployment and Refinement:

Depending on the project scope, consider deploying the system in a controlled environment for further testing and real-world data collection. Continuously refine the system based on obtained feedback and performance metrics, aiming for optimal accuracy and robustness.



# Feasibility Plan

## Resource Requirement

### Expertise of the Team

As a well-rounded team, each one of us possesses unique strengths that contribute significantly towards building an innovative automated electric meter reading mobile app based on image processing techniques. We boast diverse skill sets acquired by studying pertinent subjects across artificial intelligence, cloud technologies, databases, and UI/UX design principles. Fueled by our shared passion for this ambitious endeavor, we are committed to delivering it successfully within stipulated timelines through close collaboration among team member

### Tools / Technology

|  |  |
| --- | --- |
| Tool/Technology | Description |
| Image Processing Libraries (e.g., OpenCV, scikit-image) | Provide functionalities for image manipulation, noise reduction, resizing, and other preprocessing tasks. |
| Machine Learning Frameworks (e.g., TensorFlow, PyTorch) | Offer tools for building, training, and deploying AI models like Convolutional Neural Networks (CNNs) for digit recognition. |
| Computer Vision Libraries (e.g., OpenCV, scikit-image) | Contain algorithms for object detection and segmentation, aiding in identifying and isolating the meter region within the image. |
| Programming Languages (e.g., Python) | Provide a versatile platform for developing the system and integrating various libraries and frameworks. |
| User Interface Development Tools (e.g., Tkinter, PyQt) | Enable the creation of a user-friendly interface for capturing images, displaying readings, and potentially managing historical data. |
| Figma | A design tool that can be used to prototype the user interface of the system, allowing for efficient iteration and user testing before development begins. |

### Budget

|  |  |  |
| --- | --- | --- |
| Tool/Technology | **Cost** | Description |
| Image Processing Libraries (OpenCV, scikit-image) | Free | Open-source libraries, no direct cost. |
| Machine Learning Frameworks (TensorFlow, PyTorch) | Free | Open-source frameworks, no direct cost. |
| Computer Vision Libraries (OpenCV, scikit-image) | Free | Refer to Image Processing Libraries above. |
| Binding and Documentation | 3500 PKR | Compilation of FYP book. |
| User Interface Development Tools (Tkinter, PyQt) | Free | Open-source libraries, no direct cost. |
| Figma | 9,000 PKR approx. 2 months | Free plan offers limited features, paid plans start at $12/month per editor. |
| AWS (Optional) | Variable (10,000 PKR) | Costs depend on specific services used and usage level. Free tier available for some services. |
| Misc | 1500 PKR | For Form A and B and other photocopies |
| Block Chain Gas Fee | $80- $100 | Data storage in block chain |
| API’s | $15 - $25 | API’s would be used in block chains and cloud model and plans |

## Risks Involved

* Data privacy and security: Ensuring user data privacy and implementing secure storage are crucial
* Model bias**:** Training data bias can lead to inaccurate readings for certain meter types or lighting conditions. Mitigating this requires careful data selection and diverse datasets.
* Technical challenges**:** Expertise in image processing, machine learning, and potentially cloud computing is required. Collaboration with specialists or leveraging pre-trained models may be necessary.
* System limitations**:** The system might not perform flawlessly under all conditions (e.g., extreme weather, damaged meters). Robust error handling and consideration of limitations are critical.

Ethical considerations**:**

Replacing traditional meter reading methods with AI raises questions about job displacement. Transparency and responsible implementation are crucial throughout the development process.

# Key Milestones and Schedule

## Key Milestones

Following are the major milestones of the project and their related information.

**Table ‎6‑1: Breakdown of work in form of milestones**

|  |  |  |
| --- | --- | --- |
| Milestone | Description | Estimated Effort (hours) |
| 1. Data Collection | Gather a diverse dataset of electric meter images. | 30 |
| 2. Data Preprocessing | Clean and prepare the collected image dataset. | 42 |
| 3. Meter Identification and Segmentation | Design and implement algorithms to identify and isolate the meter region within images. | 38 |
| 4. Model Selection and Training | Choose and train an AI model for digit recognition using the preprocessed data. | 40 |
| 5. System Integration | Integrate the developed components - image acquisition, preprocessing, meter identification, and digit recognition - into a functioning system. | 26 |
| 6. User Interface Design | Design a user-friendly interface for capturing images and displaying meter readings. | 25 |
| 7. Initial Testing | Test the system's functionality and accuracy on a separate test dataset. | 25 |
| 8. Final Testing | Perform comprehensive testing of the entire system to ensure functionality and accuracy. | 23 |
| 9. Deployment | Deploy the system in a real-world environment and ensure smooth operation. | 25 |
| 10. Maintenance | Provide ongoing maintenance and support for the deployed system. | 14 |

Description related to the above table here.

Project Development Stages:

This project will be completed in a series of key stages, each contributing to the successful development of the AI-based electric meter reader

1. Data Acquisition and Preprocessing (Estimated Effort: 100 hours)

Data Collection (40 hours):

The initial stage involves gathering a diverse dataset of electric meter images. This may involve collaborating with utility companies, taking pictures of various meters in different conditions, or utilizing publicly available datasets.

Data Preprocessing (60 hours):

The collected images require cleaning and preparation using techniques like noise reduction, resizing, and grayscale conversion. This ensures the data is consistent and optimized for training the AI model effectively.

2. Meter Identification and Segmentation (Estimated Effort: 80 hours)

This stage focuses on developing algorithms to identify and isolate the meter region within the captured images. Leveraging computer vision libraries, the system will be able to separate the meter from the background and focus on the area containing the meter reading digits.

3. Model Selection and Training (Estimated Effort: 120 hours)

Choosing a suitable AI model, such as a Convolutional Neural Network (CNN), is crucial for digit recognition. Once selected, the model will be trained using the preprocessed dataset. This involves feeding the data to the model, adjusting its parameters through an iterative process, and monitoring its performance to achieve high accuracy in recognizing individual digits within the meter readings.

4. System Integration and User Interface Design (Estimated Effort: 60 hours)

System Integration (40 hours): This stage involves combining the previously developed components – image acquisition, preprocessing, meter identification, and digit recognition – into a cohesive system. This creates a functional prototype capable of reading meter data.

User Interface Design (20 hours):

Designing a user-friendly interface using appropriate tools allows users to interact with the system. The interface should enable capturing meter images, displaying the recognized readings, and potentially managing historical data (if applicable).

5. Testing, Evaluation, and Documentation (Estimated Effort: 100 hours)

Initial Testing (20 hours): Initial testing focuses on evaluating the system's basic functionality and accuracy on a separate dataset not used for training. This identifies immediate issues and ensures the system functions as intended.

Refinement and Optimization (40 hours): Based on the initial testing results, the system is refined to improve its accuracy and robustness. This might involve adjusting model parameters, addressing identified issues, and potentially collecting additional data if necessary.

Final Testing and Evaluation (40 hours): Once refined, the system undergoes comprehensive testing on a larger test dataset. This evaluation compares its accuracy and efficiency with traditional meter reading methods, documenting the results for future reference.

Project Documentation (20 hours): The final stage involves compiling a comprehensive report detailing the project's methodology, achieved results, encountered challenges, and potential future improvements for the AI-based meter reader system.

These stages represent a general roadmap for developing the project. The estimated effort for each stage is a guideline and may vary depending on the specific circumstances and encountered challenges.

| **CLO** | **Description** | **Section(s) Utilized** |
| --- | --- | --- |
| Ingenuity of Idea | The project demonstrates innovative work with research value by utilizing advanced tools and technologies such as image processing libraries (e.g., OpenCV, scikit-image) and machine learning frameworks (e.g., TensorFlow, PyTorch) to automate electricity meter reading. These tools solve technical difficulties and contribute to the development of a robust system. | Tools / Technology |
| Problem Complexity and impact on Society | The project provides a design solution to complex problems by addressing challenges associated with manual meter reading. By leveraging sophisticated algorithms and computer vision libraries, the system aims to enhance accuracy, efficiency, and transparency in meter readings, thereby benefiting both utility companies and consumers. | Problem Description |
| Ethics & professionalism | The project demonstrates ethical conduct by prioritizing data privacy and security, addressing potential biases in AI models, and considering the implications of job displacement. The team ensures transparency and responsible implementation throughout the development process. | Risks Involved |
| Ability to work individually and as a team member | The project team collaborates effectively to overcome technical challenges and achieve project milestones. They exhibit adaptability and contribute constructively to solving multidisciplinary problems, ensuring the successful development and deployment of the system. | Key Milestones and Schedule |
| Communication | The project presentation and documentation are clear, organized, and engaging, facilitating understanding and collaboration. The team effectively communicates the project objectives, methodology, and results to stakeholders, ensuring transparency and alignment with project goals. | Key Milestones and Schedule, Tools / Technology, Methodology, Risks Involved, Project Development Stages |
| Documentation | The project documentation is comprehensive and well-structured, providing detailed insights into the project's methodology, milestones, and outcomes. It includes thorough documentation of tools, technologies, risks, and key milestones, enabling replication and further development of the system. | Key Milestones and Schedule, Tools / Technology, Methodology, Risks Involved, Project Development Stages |
| Lifelong learning | The project reflects a commitment to lifelong learning by exploring advanced tools and technologies, addressing technical challenges, and documenting lessons learned for future improvement. The team exhibits an intense interest in continuous self-growth and development, fostering a culture of innovation and improvement. | Tools / Technology, Risks Involved, Project Development Stages |

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## Gantt Chart

Following is the timeline divided into milestones mentioned (A sample Gantt chart; you may attach a Gantt. Chart produced by a CASE tool)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Activity** | **Weeks** | | | | | | | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | |
| Data Collection |  |  |  |  |  |  |  |  | Midterm Exam Week |  |  |  |  |  |  |  |  | Exam Week | |
| Data Preprocessing |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Meter Identification and Segmentation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Model Selection and Training |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| System Integration |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Figure ‎6‑1: SEMESTER 7 (SPRING 2024)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Activity** | **Weeks** | | | | | | | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| User Interface Design |  |  |  |  |  |  |  |  | Mid Exam Week |  |  |  |  |  |  |  |  | Exam Week |
| Initial Testing |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Final Testing |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Deployment |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Maintenance |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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