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IMPLEMENTATION OF A WEB-BASED ENERGY CONSUMPTION SYSTEM USING PYTHON AND TESSERACT OCR ALGORITHMS

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РЕАЛІЗАЦІЯ ВЕБОРІЄНТОВАНОЇ СИСТЕМИ ЕНЕРГОСПОЖИВАННЯ З ВИКОРИСТАННЯМ ТЕХНОЛОГІЙ КОДУ PYTHON ТА АЛГОРИТМІВ ОПТИЧНОГО РОЗПІЗНАВАННЯ OCR TESSERACT

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As the cost of utilities (gas heating, electricity, and water supply) continues to rise, effective monitoring of utility costs has become critically important for ordinary citizens. Modern web-based utility expense monitoring systems are driven by key economic factors that reflect societal and technological needs and allow users to visualize and analyze their monthly expenses, monitor resource consumption in real time, and compare their own consumption with average figures or previous periods, thereby encouraging energy efficiency. Implementing such systems in a web-based format ensures access to monitoring information and minimizes manual data entry by automating report generation, which encourages utility consumers to be thrifty and adopt energy-saving habits and technologies, thereby contributing to the country's overall energy efficiency. The aim of this study is to examine the characteristics of the software implementation of a functional web-based system that will provide end users with an effective tool for visualizing and transforming visual data, as well as analyzing and monitoring utility costs, with the goal of improving financial literacy. The study consists of two phases. In the first phase, the back-end component was developed, and the API and business logic of the web system were implemented. In the second phase, the effectiveness of the implemented approach was evaluated with a view to the further implementation of a web system for monitoring utility costs in individual households. A functional web system has been developed that enables effective monitoring of utility costs by converting visual data from a home network of smart cameras into digital readings using OCR (Optical Character Recognition) technology based on the Tesseract engine, with the aim of further monitoring energy consumption. All components of the backend software implementation have been described and annotated to facilitate a better understanding of their use. The system for collecting monitoring data from a network of smart cameras at key locations within an apartment has been examined in detail. The back-end component of the web system's API has been designed and implemented based on the processing of incoming visual data using the Tesseract OCR engine. The system's functionality has been tested, and an evaluation of the effectiveness of the implemented monitoring

data management approach has been conducted, enabling the convenient automatic collection of consumption meter readings from hard-to-reach locations in the household in the future.

Keywords: web system, optical character recognition, data analysis.

Introduction. One of the key aspects of providing high-quality utility services today is digital transformation in the area of monitoring utility costs and payments. The modern, high-quality functioning of the housing and utilities sector is impossible without the provision of high-quality housing and utility services, and in the context of rapid technological changes, urbanization, and growing environmental challenges, the demands on the quality of these services are constantly rising, prompting the search for innovative solutions and a rethinking of traditional approaches.

An analysis of recent studies and publications on this topic indicates that modern researchers have already attempted to implement smart web applications for data collection in automated monitoring: data collection from meters, registration of road signs, recognition of license plate characters, parking space markers, handwritten font recognition, etc. The methods proposed by researchers provide their own tools for digitizing and automating character recognition, replacing previously manual and labor-intensive procedures.

Many studies focus on the use of smart home technologies, neural networks, deep learning models, and optical character recognition (OCR) and are partly theoretical in nature.

Analysis of basic research and publications. The works of many Ukrainian researchers can be included among those that have analyzed the monitoring of performance indicators for the use of housing and utility

services. In particular, in [1–4], significant attention is devoted to a comprehensive analysis of computer vision technologies for reading energy meters, the use of smart home technologies, and data recognition using a smartphone camera; digital measurements using optical character recognition tools are discussed by experts in [5–10].

Today's utility consumers are becoming more demanding and informed, expecting not just the availability of services, but also their reliability, efficiency, transparency, and customer-centricity.

Modern utility energy metering systems consist of a set of control and measurement devices, communication lines, a computer, and software, all connected into a single system for transmitting data on consumer usage.

Thus, modern monitoring solutions in the field of utility costs are comprehensive systems that combine hardware (meters, sensors), communication technologies, and powerful software to ensure transparency, control, and efficient use of resources.

Objective. The aim of this study is to examine the characteristics of the software implementation of a functional web-based system that will provide end users with an effective tool for visualizing and transforming visual data, as well as analyzing and monitoring utility costs, with the goal of improving financial literacy.

Teaching the core material. Traditional billing systems, which rely on manual data collection and paper receipts, are a source of numerous problems: inaccuracies, delays, lack of transparency in billing, and, as a result, mistrust between consumers and service providers.

Currently, comprehensive dynamic web portals and mobile apps are becoming key to visualizing and providing access to increased transparency regarding current and past consumption, as well as calculating costs in monetary terms compared to previous periods or average figures.

Reading energy meter readings is a labor-intensive task that is, in most cases, performed manually. There are some approaches that propose the use of smart meters, which automatically report their readings. However, this solution is expensive and requires both the replacement of existing meters—even when they are functional and new—and significant changes to the entire meter reading system [4].

The implementation of “smart” meters and automated metering and monitoring systems now makes it possible to collect data in real time, detect leaks and anomalies, optimize resource consumption, and minimize losses. This not only leads to savings for consumers but also allows utility companies to improve their operational efficiency, helping them plan their activities more rationally and invest in infrastructure modernization.

Using “smart” electricity meters, industrial controllers, specialized equipment, and in-house software, ready-to-use solutions for automated integrated energy resource metering systems are currently being developed and are already in use.

Currently, software solutions are already available in Ukraine that integrate functions such as calculating and generating bills, calculating arrears, and generating customer invoices, among others.

Despite the obvious advantages, monitoring utility costs faces a number of challenges: the high initial cost of equipment and system deployment is a significant barrier, especially for countries with limited budgets or for older housing stock; data security and privacy protection are critically important aspects, as the systems collect sensitive information about consumer behavior, etc.

Despite these challenges, the path toward full digitalization and integration is irreversible. This is an investment not only in infrastructure modernization but also in improving quality of life and building trust between the public and the utility sector.

Modern wireless meter reading systems enable the fulfillment of all set objectives by providing the following functions:

- contactless collection of energy consumption data from electricity meters;
- remote balance monitoring;
- the presence of non-volatile memory in the equipment used, which records all unauthorized actions directed at the data collection system;
- the possibility of unlimited expansion of the polling network [5].

The monitoring process includes several key stages: data collection, data processing, control of standards and tariffs, data visualization—reporting, consumption optimization, integration with modern technologies—service quality control. Traditional meters (mechanical water meters, induction electricity meters) measure the volume of the consumed resource but are not capable of automatic data transmission.

The development and implementation of automated utility consumption monitoring systems remain promising areas today, based on a wide range of advanced technical solutions that incorporate primary data collection devices—sensors and meters. Thus, traditional analog devices are being replaced by smart meters, which represent a technological breakthrough with their electronic components and radio communication modules. Unlike their mechanical predecessors, they not only record resource consumption but also automatically transmit this data. This eliminates the need for manual meter reading, minimizes the human factor, and consequently, errors and opportunities for manipulation.

“Smart” electricity meters are equipped with electronic modules for digital consumption measurement and built-in communication interfaces. Currently, they already have built-in pulse sensors or ultrasonic sensors for accurate measurement of water, gas, and electricity consumption, as well as modules for wireless data transmission.

Smart meters can collect information at high frequency (hourly or even more frequently), providing a detailed consumption profile. This level of detail is the

first step toward transparency, allowing consumers and suppliers to see when and how much of a resource has been used.

The implementation of such systems not only leads to significant savings in resources and financial costs but also radically transforms the relationship between consumers and service providers. Consumers gain the tools to manage their consumption in an informed manner, while utility companies receive the data needed to optimize networks, respond promptly to outages, and make informed management decisions.

Further developments in artificial intelligence, quantum computing, and new communication technologies will only intensify this transformation, opening new horizons for monitoring and managing utility costs.

The main idea behind our research project was to deploy a network of smart cameras at key locations in the apartment where utility meters are located: water, gas, and electricity meters. These cameras, equipped with computer vision capabilities and the ability to transmit data via Wi-Fi, can perform a number of important tasks.

The process of collecting meter readings was developed as a personal solution to facilitate the automatic collection of meter readings (for water, gas, and electricity). Instead of manually visiting and recording readings, smart cameras enable the recognition of numbers from meter displays and the instant transmission of this data to a centralized system. This monitoring streamlines the process, minimizes human error, and eliminates the need for regular access to residences for inspections.

Monitoring was conducted via a custom-developed web system that displayed the collected data, generated consumption graphs, and provided the administrator with comprehensive oversight of utility payments.

All data received from the cameras is stored on a local server, where it is analyzed using specialized software we developed. This allows us to generate consumption reports, forecast resource needs, identify malfunctions, and optimize the distribution of utility services.

The meter reading process was developed as a customized solution to streamline the automatic collection of consumption data (for water, gas, and electricity). Instead of manually visiting sites and recording readings, smart cameras recognize the numbers on meter displays and instantly transmit this data to a centralized system. This monitoring optimizes the process, minimizes the likelihood of human error, and eliminates the need for regular visits to residences for inspections.

Monitoring was carried out using a specially developed web system that displayed the collected data, generated consumption graphs, and provided the administrator with a complete overview of utility payments.

All data received from the cameras is stored on a local server, where it is analyzed using specialized software developed by us. This allows us to generate

consumption reports, forecast resource needs, identify malfunctions, and optimize the distribution of utilities.

Our study utilized the following technical devices: three Thiryo Z2 security cameras with automatic tracking (1440P HD WiFi, day/night vision, motion alerts – USB-powered, 355° horizontal and 90° vertical rotation, two-way audio, for indoor home surveillance, 3MP, anti-fog lights, AI motion detection, cost – \$6.24/unit).

Software technologies integrated into the web-based utility cost monitoring system:

- Python – an interpreted, high-level, general-purpose programming language;
- SQLite – a relational database management system (DBMS);
- HTML/CSS – HyperText Markup Language/Cascading Style Sheets;
- JavaScript – a scripting language (Chart.js);
- APScheduler – a task scheduler library for Python that allows scheduling the execution of functions in the future: once or periodically;
- Tesseract OCR – (via pytesseract) – an open-source optical character recognition engine.

Results and Discussion. Traditional heuristic image processing methods are unable to cope with changes in the environment for optical character recognition (OCR), which is why solutions based on artificial intelligence (AI) and computer vision are used [5].

A smart electricity metering system can solve these problems. Wireless systems based on the Internet of Things (IoT) for smart electricity meters enable automatic meter reading, avoiding billing errors or human errors during meter reading [6].

An integrated system utilizing the Internet of Things and digital image processing with a faster convolutional neural network enables the fastest measurement time in real-time mode [7].

The combination of these technologies has made it possible to increase productivity by optimizing consumption and facilitating access to real-time information. The approaches proposed by researchers simplify the collection, storage, and analysis of real-time energy monitoring data to facilitate management and minimize consumption for users [11].

The typical method of meter reading used by electricity distribution companies is outdated and cumbersome, as it relies on a manual process of taking meter readings by a person and subsequently updating the server with the new readings. The smart web application with a web server developed by the authors enables the collection of data from electricity meters and its subsequent transmission to a database/server for calculation and analysis using optical character recognition [12].

Article [13] has already proposed an attempt to combine advanced tools and approaches for optimizing spatial data in the context of municipal management based on modeling a developed prototype of an interactive housing and utilities management system.

The Internet of Things has already unlocked the potential for electronic devices, systems, and applications that can reduce resource consumption in urban environments by leveraging smart water meter systems and microcontrollers via web platforms or mobile apps to provide comprehensive real-time data to facilitate decision-making [14].

The growing need for effective monitoring of electrical voltage led to the development of an intelligent data collection system. The main goal of the system is to ensure automatic meter reading using a neural network trained to recognize digits. The software component, implemented by the authors in Python, allows for image capture when the system is deployed as a desktop web application [8].

The goal of this work was to develop an artificial intelligence model based on deep learning, optical character recognition (OCR) algorithms, and artificial intelligence, which allows us to detect and extract water meter numbers.

Using software that provides a complete set of tools for software development within a single integrated user interface—the open-source version of the PyCharm Integrated Development Environment (IDE)—the development process was carried out, making it faster, more efficient, and less prone to errors.

However, system testing revealed that the developed code works well under the Linux operating system. An attempt to test the system's data-reading functionality in PyCharm: Community Edition under Windows resulted in data-reading errors. Tesseract required specific data files for recognizing certain languages. When working with PyCharm Community Edition, it was necessary to download and install Tesseract OCR (for example, the .exe file for Windows) because the code could not run using only Python libraries. Therefore, as a result of the research, a decision was made to migrate the project from a local environment (PyCharm) to a cloud-based one (Replit).

So, for the demonstration, we chose this powerful online development environment, Replit (<https://replit.com/>), which allowed us to write, run, and share code directly in the browser. Its main advantage was that there was no need to install anything on your computer—all the tools ran in the cloud. Since Replit is a cloud service, it works in any modern browser (Firefox, Chrome, Brave, etc.). On any Linux distribution (Ubuntu, Fedora, Arch, Mint, etc.).

Modern open-source Tesseract character recognition mechanisms allow for increased efficiency and effectiveness of procedures in optical character recognition systems, and Python, using the OpenCV library, simultaneously promotes sustainable cost-cutting measures [3].

Tesseract OCR has emerged as a powerful, flexible, and free text recognition tool that, despite some limitations, is the de facto standard among open-source OCR engines and is actively developed by the community and Google. The Tesseract text recognition process consisted of several stages: image pre-

processing, text recognition, and post-processing. Open-source code and free availability became one of Tesseract's greatest advantages, as it was completely free for personal use.

Tesseract was designed as a command-line engine, but it can be easily integrated into other programs using an API.

After that, the ability to upload photos of meters was implemented. To enable the program to read the numbers from these photos, the OpenCV, PIL, and Tesseract libraries were integrated. They handled image processing: first, the photo is cleaned up, enlarged, and color-corrected; then Tesseract reads the text and returns the information as text—that is, the actual numbers. These digits were verified and converted into standard numbers, which were then recorded in the database.

The following libraries were used to write the Tesseract text recognition subroutine:

```
import sqlite3
from flask import Flask, render_template, request,
redirect, url_for, flash, session, get_flashed_messages,
jsonify
from werkzeug.security import
generate_password_hash, check_password_hash
from apscheduler.schedulers.background import
BackgroundScheduler
import random
import datetime

import cv2
import numpy as np
from PIL import Image
import pytesseract
```

The following image processing steps were implemented for the data acquired from the meters:

```
def recognize_digits_adapted(image_pil):
    import numpy as np
    import cv2
    import pytesseract
    image = np.array(image_pil.convert('RGB'))
    image = cv2.cvtColor(image,
cv2.COLOR_RGB2BGR)

    # Zoom:
    image = cv2.resize(image, None, fx=4, fy=4,
interpolation=cv2.INTER_CUBIC)

    # Conversion to grayscale:
    gray = cv2.cvtColor(image,
cv2.COLOR_BGR2GRAY)
    gray = cv2.GaussianBlur(gray, (3, 3), 0)
    _, thresh = cv2.threshold(gray, 0, 255,
cv2.THRESH_BINARY_INV +
cv2.THRESH_OTSU)

    # Morphology:
    kernel =
cv2.getStructuringElement(cv2.MORPH_RECT, (2, 2))
```

```
thresh = cv2.morphologyEx(thresh,
cv2.MORPH_CLOSE, kernel)
```

```
# Highlighting of outlines (numbers):
contours, _ = cv2.findContours(thresh
cv2.RETR_EXTERNAL,
```

```
cv2.CHAIN_APPROX_SIMPLE)
```

```
# Filtering only large-scale patterns (noise
reduction):
```

```
digit_regions = []
for cnt in contours:
    x, y, w, h = cv2.boundingRect(cnt)
    if h > 20 and w > 10: # ці пороги можна
налаштувати
        digit_regions.append((x, y, w, h))
```

```
if not digit_regions:
    return ""
```

```
# Finding the range of the entire set of numbers:
x_min = min(x for x, y, w, h in digit_regions)
y_min = min(y for x, y, w, h in digit_regions)
x_max = max(x + w for x, y, w, h in digit_regions)
y_max = max(y + h for x, y, w, h in digit_regions)
```

```
roi = thresh[y_min:y_max, x_min:x_max]
```

```
# Optimizing Tesseract settings:
custom_config = r'--oem 3 --psm 7 -c
tessedit_char_whitelist=0123456789.,'
```

```
result = pytesseract.image_to_string(roi,
config=custom_config)
```

```
# Character cleaning:
clean = ".join(c for c in result if c.isdigit() or c in
['.', ','])
clean = clean.replace('.', ',').strip()
```

```
return clean
```

```
@app.route('/upload_readings',
methods=['POST'])
```

```
def upload_readings():
    if 'user_id' not in session:
        return redirect(url_for('login'))
```

```
user_id = session['user_id']
now = datetime.datetime(2025, 9, 1)
month = now.month
year = now.year
```

```
readings = {}
not_recognized = []
```

```
for meter_type in ['electric', 'gas', 'water']:
    file
    request.files.get(f'{meter_type}_image')
```

```
if file and file.filename:
```

```
try:
```

```
image = Image.open(file.stream)
digits
```

```
recognize_digits_adapted(image)
```

```
if digits:
```

```
try:
```

```
value = float(digits)
readings[meter_type] = value
print(f"✅ {meter_type.upper()} →
```

```
{value}")
```

```
except ValueError:
```

```
not_recognized.append(meter_type)
```

```
print(f"❗ Немає можливості
```

```
перетворити в число: {digits}")
```

```
else:
```

```
not_recognized.append(meter_type)
```

```
print(f"❗ {meter_type.upper()} не
```

```
розпізнано")
```

```
except Exception as e:
```

```
print(f"❗ Помилка обробки
```

```
{meter_type.upper()}: {e}")
```

```
not_recognized.append(meter_type)
```

```
if not readings:
```

```
print(f"❗ Жодного показника не зчитано.")
```

```
return
```

```
redirect(url_for('show_info_utility_costs'))
```

```
try:
```

```
with sqlite3.connect(DATABASE) as conn:
```

```
c = conn.cursor()
```

In general, reading meter readings from photos worked by having the user upload a photo of the meter (electricity, gas, or water). Using Tesseract OCR technology to read the numbers, the system first processed the image (converting it to grayscale, and applying filters) and extracted only the first 5 digits, then saved the recognized values and displayed a message indicating whether the readings were successfully or unsuccessfully read.

The use of OCR (optical character recognition) to read meter readings is a highly relevant field, as it bridges the gap between older analog meters and modern digital systems.

To visualize the process of monitoring readings from three surveillance cameras (electricity meter, gas meter, and water meter), it was planned to transmit image data to the administrator's web application. Figure 1 shows the modular design of the components of the utility consumption monitoring web system. Cameras 1, 2, 3 (IP camera/smart camera): These are devices for capturing readings from data sources. Modern IP cameras/smart cameras can stream video, send individual images, or even transmit metadata (e.g., meter readings, recognized characters, temperature, humidity, if the camera has such built-in functions or connected sensors). The following were used to monitor "readings":

- a video stream or photo that the administrator reviews manually, based on which real-time recognition and conversion of data into electronic format occur;
- image analysis, from which digital readings are extracted using Tesseract OCR.

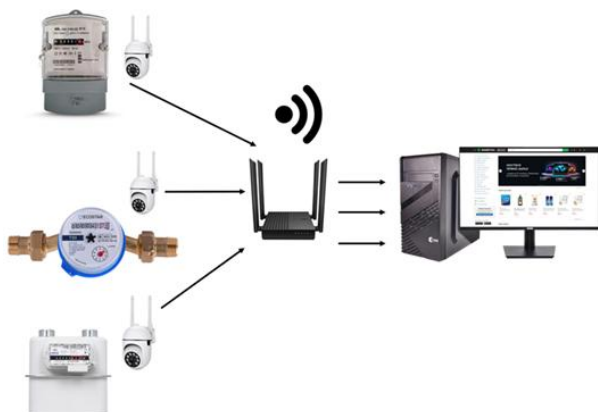


Fig. 1. Modular Design of Web System Components

The network infrastructure utilized data transmission via Wi-Fi. Each camera is connected to the nearest access point via Wi-Fi. These could be individual access points or a single high-performance Wi-Fi router serving as both an Internet access point and a communication channel for transmitting data from surveillance locations to the central server. The data flow was clearly defined as Camera -> Wi-Fi -> Access Point -> Router -> Internet -> Server -> Web Application.

After collection, the data is transmitted to the central server, where specialized software for managing massive amounts of meter data can be used for data processing and analysis (the backend).

The frontend development was designed to build a user interface that runs in the administrator's web browser. It interacts with the server (backend) via an API to:

- display live video/photo feeds from cameras;
- display recognized metrics (charts, tables, dashboards);
- show the history of metrics and their changes;
- allow the administrator to manage cameras/photos (e.g., change settings, view archives);
- notify of anomalies (e.g., sudden changes in metrics, loss of connection with a camera).

It was decided to create the interface of the utility cost monitoring web system based on a comprehensive approach.

The main page of the web system was built using HTML, which was designed to display text labels showing the initial and final meter readings and to provide video monitoring of the meters via online cameras. CSS was used to style the elements on the page, such as font sizes, spacing between blocks, colors, and so on. Python enabled the interactive behavior of the interface, specifically its response to user actions: calculating differences in readings, working with the

database, and generating statistical charts as shown in Figure 2.

Fig. 2. Web system page for entering current metrics

Based on the functional requirements for the web system, its main components were identified:

- main menu;
- section containing user registration information;
- a section containing information on the recording of meter readings;
- a section containing monitoring data in the form of charts;
- a section containing information on consumption monitoring in Figure 3.

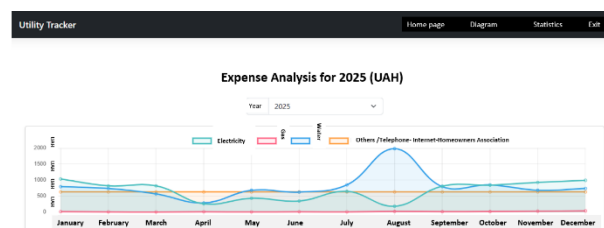


Fig. 3. Web page for visualizing utility consumption

Web-based systems for monitoring utility costs are already an indispensable tool for improving transparency, efficiency, and control over resource consumption. They provide automated data collection, visualization, and basic analysis, enabling consumers and utility companies to better understand the structure of their expenses.

Low accuracy in recognizing meter readings using Tesseract OCR is a common problem. This is because Tesseract is primarily configured to work with clean, printed text (documents), whereas images of meters present significant visual challenges.

As a result of testing the system on three sets of meter readings, a qualitative assessment of the conversion was obtained only from the gas meter readings (Figure 4). For the other photos, image quality depended heavily on the quality of the input image: low resolution, noise, blurriness, poor contrast, excessive tilt, or complex backgrounds significantly reduced recognition accuracy, leading to errors in the obtained data.



Fig. 4. High-quality raw data on gas meter readings obtained as a result of system testing

This experiment can be explained by the following reasoning: During optical character recognition, the Tesseract OCR engine detected white digits on a black background and red digits on a white/light background as having very high contrast with the background, which significantly facilitated their separation (segmentation) from the background for the recognition algorithms. Additionally, the digits on the meter featured a simple, clear, standardized, machine-readable font that is well-trained in Tesseract models.

Insufficient contrast between the digits and the background (for example, light digits on a light background or dark digits on a dark background) when photographing readings from other meters (electricity, water) clearly complicated the segmentation and recognition of other meters, so the data was distorted during reading, not all digits were displayed, etc.

Uneven lighting, glare, and shadows falling on the digits can distort their appearance, causing Tesseract to misinterpret the characters; this also applies to old or dirty meter dials.

As a result of our research, recommendations were formulated to improve recognition and accuracy; work needs to be done in three areas: improving the source, enhanced preprocessing, and fine-tuning the OCR configuration.

The biggest and most significant drawback of Tesseract, which is particularly evident when recognizing digits. Digits are often small elements in an image, and any visual defects can lead to errors.

High-quality recognition of meter readings (water, gas, electricity) requires a combination of reliable hardware, computer vision methods, and modern OCR algorithms.

The following recommendations may serve as a basis for further research in this area:

- Improving the camera setup (physical adjustments), enhancing lighting quality, and reducing glare to stabilize the lighting on the subject;
- Securely mount the camera and lock its focus (if adjustable), ensuring it is precisely focused on the plane of the digits;
- Pre-process the image for Tesseract to be as clean as possible, in black and white, with clear contours;
- Use the strictest possible recognition parameters (restricting Tesseract to digits and periods/commas only)

and utilize specialized models or libraries trained on 7-segment displays, etc.

The best results for high-quality recognition can be achieved not only with powerful OCR but also with high-quality preprocessing (OpenCV) and logical validation of the recognized values. For commercial or high-precision use, more complex image processing logic will be required (for example, OpenCV for automatically selecting the area with numbers before OCR) or the use of specialized deep learning models (for example, YOLO or CNN).

Implementing image preprocessing is a critical step for minimizing errors in Tesseract OCR. Tesseract works best with “ideal” images: black text on a white background, high resolution, and no noise. Reading meter readings (gas, water, electricity) is a specific task that differs significantly from document scanning. This process presents challenges such as glare on glass, specific fonts, extraneous noise, slanted digits, and more.

Tesseract often makes mistakes if the photo is blurry, taken at an angle, or in poor lighting (which is typical for storage rooms or basements where meters are located). Research into image preprocessing methods (OpenCV) before feeding images into Tesseract includes adaptive binarization, perspective correction, and removal of flash glare on the meter glass.

Research into the possibility of moving recognition directly to the client side (browser) using TensorFlow.js allows for real-time digit recognition via the camera without sending the photo to the server. If OCR reads the wrong digit, the system should automatically compare it with the previous month’s data and ask the user to confirm the information to avoid anomalies in reports.

Data transmission in utility cost monitoring systems requires secure and stable communication channels. Analytical network and server technologies are radically changing the approach to accounting for and monitoring utility costs.

When using Tesseract OCR to improve recognition of complex images, it may be helpful to generate Python scripts using OpenCV that can perform adaptive binarization and text alignment specifically for Tesseract processing, as well as implement Tesseract version 4.0+ with a neural network, which handles noisy text better than older versions.

Using a specially trained Tesseract model will help incorporate an algorithm for “gluing” segmented digits, and object recognition using a neural network will provide a 20–30% accuracy boost for electronic displays and allow for the removal of extraneous background from digits in photographs of mechanical counters. Further development of such platforms should be aimed at transforming them into full-fledged intelligent resource management systems.

Conclusions. To summarize the above, it is worth noting that the development and creation of new information systems for monitoring utility costs enables the consolidation of data from various sources (service providers, meters) into a single, user-friendly interface, replacing paper bills and numerous separate websites.

The scientific novelty of the results lies in the fact that, for the first time, a budget model of an integrated web-based utility cost monitoring system has been developed, which provides a unified representation of diverse visual data aimed at adjusting and managing utility costs to optimize the budget.

The functional web system is implemented as an information platform using the most affordable consumer-grade webcams (Thirtytwo Z2 models) in combination with standard Python software, providing an alternative to expensive industrial “smart meters” with remote data transmission and reducing financial costs by a factor of 3–4. Cost calculations and monitoring are performed directly on the consumer’s computer without the need for complex cloud-based or expensive specialized platforms.

The practical significance lies in the immediate usefulness and applicability of the results for various user groups: retirees, people with disabilities, and thrifty citizens, who will be able to reduce their utility costs through precise monitoring by deploying a network of smart cameras at key points in the apartment where utility meters are located, with the ability to conveniently and automatically collect meter readings from hard-to-reach areas of the household.

The implementation of this comprehensive information system is tailored for vulnerable and budget-conscious segments of the population to help optimize household budgets, offering a fast return on investment and a low break-even point.

Prospects for further research include improving image preprocessing algorithms using the OpenCV library to enhance the accuracy of text recognition by the Tesseract engine under low-light conditions and geometric distortions, as well as developing automatic segmentation modules for the region of interest (ROI) to identify numerical readings on meters of various types and designs.

Research into the possibilities of integrating lightweight neural network models for data recognition and the implementation of intelligent systems for verifying readings based on the analysis of historical consumption data to prevent errors during automated data entry may also become relevant.

Література

1. Spichkova M. Comparison of Computer Vision Approaches in Application to the Electricity and Gas Meter Reading / Maria Spichkova, Johan van Zyl, Siddharth Sachdev, Ashish Bhardwaj // *Communications in Computer and Information Science*. 2020. DOI: https://doi.org/10.1007/978-3-030-40223-5_15.
2. Spichkova M. Application of Computer Vision Technologies for Automated Utility Meters Reading / Maria Spichkova, Johan van Zyl // In *Proceedings of the 15th International Conference on Software Technologies (ICSOFT 2020)*. 2020. P. 521-528. URL: <https://www.scitepress.org/Papers/2020/98925/98925.pdf>.
3. Dergachov K. Development of tools for information protection of optical text recognition systems / Konstantin Dergachov, Leonid Krasnov, Vladislav Bilozerskyi, Anatolii Zymovin // *Radioelectronic and Computer Systems*. 2022. No 2. P. 159-177. DOI: <https://doi.org/10.32620/reks.2022.2.13>.
4. Gayer A. Real-time automatic water meters recognition on edge devices / Alexander Gayer, Vladimir Arlazarov / In: *Eighteenth International Conference on Machine Vision (ICMV 2025)*. 2026. P. 37-44. URL: <https://www.deepdyve.com/lp/spie/real-time-automatic-water-meters-recognition-on-edge-devices-Xn0BP6Oatt>.
5. Amudha J. Wild OCR: Deep Learning Architecture for Text Recognition in Images / Amudha Joseph, Manmohan Singh Thakur, Anupriya Shrivastava, Shubham Gupta // In: *Proceedings of International Conference on Computing and Communication Networks*. 2022. Vol 394. P. 499-506 DOI: https://doi.org/10.1007/978-981-19-0604-6_46.
6. R. S., R R. Gandhi. Smart Measuring Device for Power with Digital Debiting System Using Mobile Application Tool / Rajesh Sharma Rajendran, Rajiv Gandhi, Akey Sungheetha, Chinnaiyan Ramasubramanian // *2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM)*, Noida, India. 2024. P. 1-6. URL: https://www.researchgate.net/publication/381680978_Smart_Measuring_Device_for_Power_with_Digital_Debiting_System_Using_Mobile_Application_Tool.
7. Lubis F. Erna Budhiarti Nababan, Pauzi Ibrahim Nainggolan, et al. Integrated Smart Parking System Using Internet of Things (IoT) and Digital Image Processing with Faster Region Based Convolutional Neural Network (Faster R-CNN) and Optical Character Recognition (OCR) / Fahrurrozi Lubis, Erna Nababan, Pauzi Ibrahim Nainggolan, Mohammad Fadly Syahputra University of North Sumatra // *2024 8th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, Medan, Indonesia. 2024. P. 342-348. DOI: <https://doi.org/10.1109/elticom64085.2024.10864954>.
8. Ramos J. Sistema Inteligente de Adquisición de Datos para la Monitorización de Tensión Eléctrica Mediante Redes Neuronales / Josnier Ramos Guardarrama, Maykop Pérez Martínez, Orestes Hernández, Raimundo Silvério // *Revista Politécnica*. 2025. Vol. 56, No 1. P. 95–104. DOI: <https://doi.org/10.33333/rp.vol56n1.08>.
9. Fajrianti E. A Proposal of OCR-based User Positioning Method in Indoor Navigation System Using Unity and Smartphone / Evianita Dewi Fajrianti, Nobuo Funabiki, Amma Liesvarastranta Haz, Sritrasta Sukaridhoto (INSUS) // *ICNCC '23: Proceedings of the 2023 12th International Conference on Networks, Communication and Computing*. 2023. P. 99–105. URL: <https://dl.acm.org/doi/pdf/10.1145/3638837.3638852>.
10. Morkun V.S. Development of a method for studying traffic of multiservice networks / Morkun V.S., Hryshchenko S. M., Nizhehorodtsev V.O., Filonenko

- M.M., Lagovsky V.V. // Radio Electronics, Computer Science, Control. 2023. No 2. P.125-133. DOI: <https://doi.org/10.15588/1607-3274-2023-2-13>.
11. Ktari J. Lightweight AI Framework for Industry 4.0 Case Study: Water Meter Recognition / Ktari, Jalel, Tarek Frikha, Monia Hamdi, Hela Elmannai, and Habib Hmam // Big Data and Cognitive Computing 6. 2022. Vol. 6. No 3. P. 72. URL: https://www.researchgate.net/publication/361713665_Lightweight_AI_Framework_for_Industry_4_0_Case_Study_Water_Meter_Recognition.
 12. Sultana U. Smart OCR Application for Meter Reading / Sultana, Umbrin & Bilal, Sannad & Naqvi, Syed & Iqbal, Rafay // Engineering Proceedings. 2022. Vol. 20. No 25. DOI: <https://doi.org/10.3390/engproc2022020025>.
 13. Konovalenko S., Krasenko, A., Sezonchuk, S., Bilous, I., Trunova, E.. An Interactive System for Monitoring the State of Urban Infrastructure / Konovalenko S., Krasenko, A., Sezonchuk, S., Bilous, I., Trunova, E // In: Information Technology for Education, Science, and Technics. ITEST 2024. Lecture Notes on Data Engineering and Communications Technologies. Springer, Cham. 2024. Vol 221. URL: https://www.researchgate.net/publication/384577491_An_Interactive_System_for_Monitoring_the_State_of_Urban_Infrastructure.
 14. Varghese L. J. IOT Based Smart Water Meter and Electricity Meter for Domestic Utilities / L. J. Varghese, V. Devanath, V. Kishore and R. Poornima // 2025 IEEE International Conference on Intelligent Signal Processing and Effective Communication Technologies (INSPECT), Gwalior, India. 2025. P. 1-6. URL : https://www.researchgate.net/publication/400198710_IOT_Based_Smart_Water_Meter_and_Electricity_Meter_for_Domestic_Utilities.

Ніжегородцев В.О., Філоненко М.М., Лаговський В.В., Грищенко С.М., Реалізація веборієнтованої системи енергоспоживання з використанням технологій коду Python та алгоритмів оптичного розпізнавання OCR TESSERACT

В умовах зростання вартості комунальних послуг (газове опалення, електроенергія, водопостачання) ефективний моніторинг витрат стає критично важливим для пересічних громадян. Сучасні вебсистеми з моніторингу комунальних витрат обумовлені економічними ключовими факторами, що відображають суспільні та технологічні потреби та дозволяють користувачам візуалізувати та аналізувати свої щомісячні витрати, контролювати споживання ресурсів у реальному часі, порівнювати власне споживання з середніми показниками або попередніми періодами, стимулюючи до енергоефективності. Реалізація вебформату таких систем дозволяє забезпечити доступ до моніторингової інформації та зводить до мінімізації ручного введення даних на автоматичне формування звітів, що стимулює споживача комунальних послуг до ощадливості та до реалізації енергоощадних звичок та

технологій, сприяючи загальній енергоефективності країни.

Метою дослідження є вивчення особливостей програмної реалізації функціональної вебсистеми, яка забезпечить кінцевим користувачам ефективний інструмент для візуалізації, перетворення візуальних даних, аналізу та контролю витрат на комунальні послуги з метою підвищення фінансової грамотності.

Дослідження складається з двох етапів. На першому етапі було розроблено back-end частину та здійснення реалізації API та бізнес-логіки вебсистеми. На другому етапі було проведено оцінку результату відповідності ефективності впровадженого підходу з метою подальшої реалізації вебсистеми з моніторингу комунальних витрат в умовах індивідуального домогосподарства.

Розроблено функціональну вебсистему, що забезпечує ефективний моніторинг комунальних витрат шляхом перетворення візуальних даних з домашньої мережі смарт-камер у цифрові показники на основі технології оптичного розпізнавання символів OCR на базі рушія Tesseract з метою подальшого контролю енергоспоживання. Всі компоненти програмної реалізації backend-частини системи були описані та прокоментовані для кращого розуміння їх використання.

Детально розглянуто систему збору моніторингових показників з мережі смарт-камер у ключових точках квартири. Реалізовано, спроектовано back-end частину API вебсистеми на основі обробки вхідних візуальних даних за допомогою рушія Tesseract OCR. Протестований функціонал системи та проведена оцінка результатів ефективності впровадженого підходу керування моніторингових даних дозволяє в подальшому здійснювати комфортний автоматичний збір показників лічильників споживання з важкодоступних місць домогосподарства.

Ключові слова: вебсистема, оптичне розпізнавання, обробка зображень, аналіз даних.

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