UDC 004.9:502.17

O.V. Pavlyk
O.N. Romanyuk

VERIFICATION METHODS FOR CLEANUP RESULTS IN SOFTWARE TOOLS FOR ENVIRONMENTAL MONITORING

Vinnytsia National Technical University

Анотація

У тезах розглядаються методи верифікації результатів прибирань у програмних засобах екологічного моніторингу. Проаналізовано підходи до автоматизованої перевірки фотодоказів із використанням комп'ютерного зору, геолокаційного підтвердження, краудсорсингової валідації та блокчейн-реєстрації. Визначено переваги та обмеження кожного методу. Запропоновано комплексну архітектуру верифікаційної підсистеми для мобільного застосунку організації міських прибирань.

Ключові слова: верифікація, екологічний моніторинг, комп'ютерний зір, геолокація, краудсорсинг, блокчейн, мобільний застосунок, прибирання міста.

Abstract

The paper examines verification methods for cleanup results in environmental monitoring software tools. Approaches to automated validation of photo evidence using computer vision, geolocation confirmation, crowdsourced validation, and blockchain registration are analyzed. The advantages and limitations of each method are identified. A comprehensive architecture for a verification subsystem of a mobile application for organizing urban cleanup events is proposed.

Keywords: verification, environmental monitoring, computer vision, geolocation, crowdsourcing, blockchain, mobile application, urban cleanup.

Introduction

The rapid growth of urban environmental initiatives has led to an increasing number of community-organized cleanup events worldwide. Digital platforms and mobile applications have become essential tools for coordinating participants, documenting activities, and reporting outcomes to municipal authorities and environmental organizations [1]. However, a critical challenge remains: ensuring the integrity and trustworthiness of reported cleanup results. Without reliable verification mechanisms, reported data may be inaccurate, fabricated, or duplicated, undermining the credibility of environmental programs and misallocating resources for incentive schemes [2].

The problem of result verification is particularly relevant in the context of gamification and reward systems built into modern ecological applications, where participants may be incentivized to exaggerate or falsify their contributions [3]. This paper presents a systematic overview of verification methods applicable to cleanup-reporting software and proposes an integrated approach suitable for practical implementation.

Verification Methods for Cleanup Results

Several distinct verification approaches have been identified in the literature and applied practice. These can be broadly categorized as: (1) automated media analysis, (2) geospatial validation, (3) social and crowdsourced verification, and (4) cryptographic and registry-based methods.

Automated Photo and Video Analysis

Computer vision techniques allow the automated assessment of submitted photographic evidence. Convolutional neural networks (CNNs) trained on datasets of before/after cleanup images can detect the presence of litter, debris density, and environmental changes [4]. Object detection models such as YOLO (You Only Look Once) can identify specific waste categories (plastic, glass, organic) and estimate the volume of collected material. Image metadata (EXIF data) is parsed to extract timestamps and GPS coordinates, providing an initial layer of authenticity confirmation. However, this approach requires substantial training data and can be circumvented by submitting pre-existing clean-area photos.

Geolocation and Temporal Validation

Geolocation-based verification cross-references the GPS coordinates embedded in submitted media with the registered cleanup event location. A spatial tolerance parameter d (measured in metres) defines the acceptable radius: if the Euclidean distance between the reported point P_r and the event centroid P_e satisfies d(P_r, P_e) <= d_max, the submission is considered spatially valid [5]. Temporal checks further require that the submission timestamp falls within the active event window. Modern platforms additionally use sensor fusion – combining GPS, Wi-Fi triangulation, and accelerometer data – to improve location accuracy and detect stationary spoofing attempts.

Crowdsourced and Peer Validation

Peer-review mechanisms leverage the community itself as a verification layer. In this model, a randomly selected subset of registered participants reviews submitted evidence and votes on its authenticity [6]. The consensus decision is computed using weighted majority voting, where trust weights w_i are assigned to reviewers based on their historical accuracy and participation history. This approach scales well with community size but introduces latency and depends on sufficient active reviewer availability. Reputation systems and anti-collusion algorithms must be carefully designed to prevent coordinated fraud.

Blockchain-Based Registration

Blockchain technology provides immutable, timestamped records of cleanup events and verification decisions [7]. Each verified submission is encoded as a transaction containing a cryptographic hash of the evidence media, event metadata, and participant identifier. The distributed ledger structure prevents post-hoc modification and enables transparent audit trails. Smart contracts can automate reward distribution upon successful verification. Despite these advantages, on-chain storage of large media files is impractical; therefore, hybrid architectures using IPFS (InterPlanetary File System) for off-chain storage with on-chain hash anchoring are preferred.

Proposed Integrated Architecture

Based on the analysis above, a layered verification pipeline is proposed for the target mobile application. The first layer performs automated EXIF metadata parsing and GPS boundary checking. The second layer applies a lightweight on-device CNN model for preliminary litter detection. Inconclusive cases are escalated to the third layer – crowdsourced peer review. Finalized results are anchored to a permissioned blockchain ledger for audit purposes. This multi-stage approach balances automation efficiency with verification reliability and minimizes the load on human reviewers [8].

Conclusions

The paper has systematically reviewed four major categories of verification methods for urban cleanup results: automated media analysis, geolocation validation, crowdsourced peer review, and blockchain-based registration. Each method presents distinct trade-offs between automation degree, fraud resistance, and implementation complexity. The proposed integrated multi-layer architecture combines the complementary strengths of these approaches and provides a practical foundation for the verification subsystem of the target software platform for organizing community ecological events in urban environments.

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Павлик Олексій Вікторович – студент групи 1ПІ-22б, факультет інформаційних технологій та комп'ютерної інженерії, Вінницький національний технічний університет, м. Вінниця, e–mail: pavlikoleksij81@gmail.com.

Романюк Олександр Никифорович – доктор технічних наук, професор, професор кафедри програмного забезпечення, завідувач кафедри програмного забезпечення, Вінницький національний технічний університет, м. Вінниця, e–mail: rom8591@gmail.com.

Pavlyk Oleksii V. – student of group 1PI-22b, Faculty of Information Technologies and Computer Engineering, Vinnytsia National Technical University, Vinnytsia, e-mail: pavlikoleksij81@gmail.com.

Romanyuk Oleksandr N. – Doctor of Technical Sciences, Professor, Professor of the Software Engineering Department, Head of the Software Engineering Department, Vinnytsia National Technical University, Vinnytsia, e–mail: rom8591@gmail.com.