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A Survey on AI-Based Environmental Activity Verification Using Image Analysis

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ABSTRACT: Promoting sustainable environmental behavior at scale requires reliable mechanisms to verify and encourage public participation. In recent years, several studies have explored the use of artificial intelligence and computer vision for automatically verifying activities such as cleanup, plantation, recycling, and eco-friendly transportation [4][5][6]. This paper presents a concise survey of AI-based approaches for environmental activity recognition and reward-based sustainability platforms. Existing deep learning methods are briefly reviewed and compared based on well-known architectures such as AlexNet, VGG, and ResNet [1][2][3][4], and key challenges such as false claims, dataset limitations, and reliability of predictions are discussed. The paper also outlines important research gaps and future directions toward building scalable and trustworthy environmental activity verification systems.

KEYWORDS: Artificial Intelligence, Computer Vision, Environmental Sustainability, Image Analysis, Activity Verification, Deep Learning.

I. INTRODUCTION

Environmental degradation caused by pollution, deforestation, and improper waste management has become one of the most critical global challenges of the modern era. While governments and organizations continue to introduce large-scale sustainability programs, the cumulative impact of individual and community-level actions such as plantation, recycling, cleanup drives, and eco-friendly transportation remains a crucial but underutilized factor. Although many digital initiatives and awareness campaigns have been launched to promote public participation, their effectiveness is often limited by the absence of transparent and scalable monitoring mechanisms. In most existing systems, activity verification is either performed manually or based on self-reported data, which is time-consuming, error-prone, and difficult to scale.

Recent advances in artificial intelligence and computer vision have created new opportunities for automated and objective verification of real-world environmental activities using visual evidence. Several studies have explored deep learning models for tasks such as waste classification, environmental scene understanding, and plantation monitoring using Convolutional Neural Networks (CNNs) and transfer learning techniques [1][2][3][5][6]. Well-known deep learning architectures such as AlexNet, VGG, and ResNet have demonstrated strong performance in large-scale image recognition tasks and have been widely adopted in environmental and visual analysis applications [1][2][3][4]. While these approaches have shown promising results, many systems still suffer from limitations related to dataset size, real-world robustness, handling of uncertain predictions, and vulnerability to false or misleading submissions [4]. In addition, sustaining long-term user engagement remains a challenge, as many platforms lack effective feedback or incentive mechanisms.

In this context, there is a clear need to systematically review and analyze existing research that combines AI, visual verification, and incentive-based approaches for environmental sustainability. This paper presents a concise survey of AI-based methods for environmental activity recognition and verification, focusing on image-based techniques and reward-oriented platforms. The objective is to compare existing approaches, identify key challenges and research gaps, and highlight future directions toward building scalable and trustworthy systems for large-scale environmental participation.

II. PROBLEM STATEMENT

Despite the growing number of digital initiatives and research efforts aimed at promoting environmental sustainability, large-scale public participation remains difficult to sustain due to the lack of reliable and scalable verification mechanisms. In most existing platforms, environmental activities are verified either manually or based on self-reported information, which makes the process time-consuming, error-prone, and vulnerable to misuse or false claims. Such approaches are not suitable for systems with a large number of users and reduce the credibility and transparency of these initiatives. In addition, many platforms fail to maintain long-term user engagement due to the absence of effective incentive mechanisms and intelligent guidance systems. These limitations highlight the need for a systematic study of automated, AI-based approaches for verifying environmental activities and supporting large-scale, trustworthy sustainability platforms.

OBJECTIVES OF THE PROJECT:

- To study and review existing AI-based methods for environmental activity recognition and verification.
- To analyze and compare different deep learning and computer vision techniques used in current research works.
- To identify key challenges such as reliability, scalability, dataset limitations, and resistance to false claims.
- To highlight research gaps and limitations in existing systems and approaches.
- To outline future research directions for building scalable and trustworthy environmental activity verification platforms.

III. LITERATURE SURVEY

The rapid development of deep learning, particularly Convolutional Neural Networks (CNNs), has significantly enhanced the performance of modern image recognition systems. Well-known architectures such as AlexNet, VGG, and ResNet have demonstrated strong capability in automatically learning discriminative features from large-scale image data [1][2][3]. These models have been widely applied in various environmental applications, including waste classification, urban garbage detection, plant monitoring, and environmental scene understanding [4][5][6]. Furthermore, the use of transfer learning with models pre-trained on large datasets such as ImageNet has enabled researchers to achieve satisfactory performance even when only limited domain-specific data is available, which is a common challenge in environmental applications [2][3][4].

Along with the progress in visual recognition techniques, several studies have investigated the use of gamification approaches, such as points, badges, and reward systems, to improve user participation in sustainability-oriented platforms. While these techniques have been shown to increase user engagement, existing literature also highlights that many current environmental platforms still depend on self-reported activities, which reduces the reliability and credibility of the collected data [4]. This limitation has encouraged researchers to explore systems that combine incentive mechanisms with automated and objective activity verification methods.

More recently, advances in generative artificial intelligence and Large Language Models (LLMs) have enabled the development of more natural and interactive user interfaces. Such models can provide intelligent guidance, answer user queries, and improve the overall user experience of digital platforms. Existing studies suggest that integrating intelligent user interaction with automated visual verification and incentive-based engagement mechanisms can lead to more effective, user-friendly, and scalable environmental sustainability systems [4].

IV. TECHNICAL ARCHITECTURE

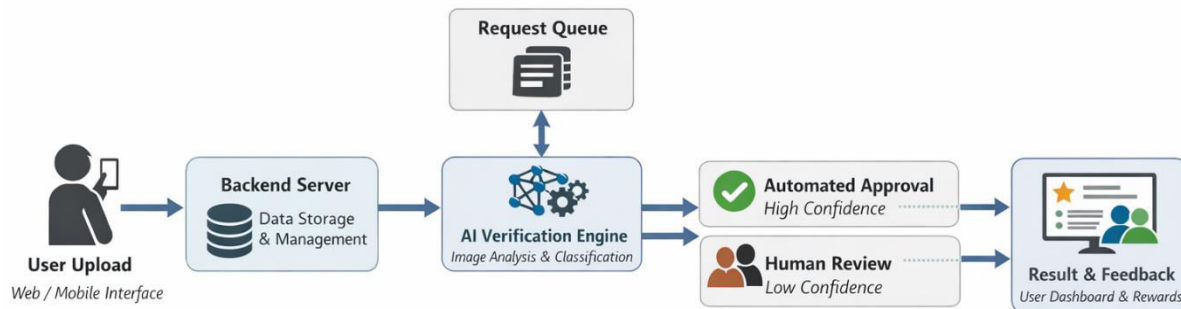


Fig. 1. General architecture of an AI-based environmental activity verification system

Figure 1 illustrates the general architecture commonly adopted in AI-based environmental activity verification platforms. Such systems typically follow a modular design in which users submit visual evidence of activities through a web or mobile interface, and the data is stored and managed by a backend server. The backend is responsible for handling user information, activity records, and communication between different components of the system in a structured and scalable manner.

After submission, the uploaded activities are usually processed through a queue-based or request management mechanism to ensure orderly and efficient handling of multiple verification requests. The core component of the architecture is the AI-based verification engine, which uses deep learning models to analyze the submitted images and extract meaningful features for classification. The model generates a predicted activity label along with a confidence or reliability score that reflects the certainty of the prediction.

Based on this confidence measure, a decision module determines the final outcome of the verification process. High-confidence predictions can be processed automatically, while low-confidence or ambiguous cases may be forwarded for human review to improve reliability and prevent incorrect approvals. Finally, the verification result is stored in the system and reflected in the user interface, allowing users to track their activity status, history, and rewards. This type of architecture provides a balanced combination of automation, scalability, and trustworthiness.

V. KEY FEATURES

1. Automated Activity Verification: Uses AI and computer vision to verify environmental activities from images.
2. Scalable Architecture: Efficiently handles a large number of users and activity submissions.
3. Confidence-Based Decision Making: Differentiates high-certainty and ambiguous verification cases.
4. Human-in-the-Loop Support: Enables manual review for low-confidence submissions.
5. Support for Multiple Activity Types: Covers cleanup, plantation, recycling, and eco-friendly transportation.
6. Integration with Incentive Mechanisms: Supports reward and gamification systems to boost participation.
7. User-Friendly Interface: Allows easy activity submission and progress tracking.
8. Transparency and Traceability: Maintains clear records of verification decisions and outcomes.

VI. FUTURE SCOPE

Future research in AI-based environmental activity verification systems can focus on expanding these platforms into large-scale, widely adopted sustainability infrastructures. One important direction is the integration of such systems with governmental or municipal organizations to enable official recognition and certification of verified activities, which would improve trust, transparency, and real-world impact. Collaboration with non-governmental and private organizations to provide real-world incentives linked to verified actions is another promising direction.

From a technical perspective, future systems can be enhanced by supporting a wider range of activity categories and incorporating video-based and location-aware verification. In addition, advances in deep learning, multimodal analysis, and generative AI can be used to improve verification accuracy, system robustness, and user interaction, helping to transform current research prototypes into scalable and trustworthy sustainability platforms.

VII. CHALLENGES AND RESEARCH GAPS

Despite significant progress in AI-based environmental activity verification systems, several challenges and open research problems still remain [4]. One of the most critical issues is the reliability of visual evidence, as systems can be misled by reused, edited, or misleading images, making it difficult to ensure that submissions truly represent real-world activities [4].

Another major challenge is dataset quality and generalization. Most existing models are trained on limited or domain-specific datasets that do not capture the wide diversity of real-world conditions such as variations in lighting, camera quality, location, and activity style [4][5][6]. As a result, models that perform well in controlled environments may fail in practical deployments [4].

Scalability and real-time performance also remain important concerns, as systems must process large volumes of submissions efficiently without compromising accuracy [4]. In addition, the balance between full automation and human verification is a key design challenge, since fully automated systems may produce incorrect decisions in ambiguous cases [4].

Finally, ethical, privacy, and misuse-related issues must be carefully addressed. The collection and processing of user-submitted images raise privacy concerns, and poorly designed systems may be vulnerable to exploitation or biased decisions [4]. These challenges highlight the need for more robust, transparent, and responsible AI-based verification frameworks.

VIII. CONCLUSION

This paper presented a concise survey of artificial intelligence-based approaches for environmental activity recognition and verification. The study reviewed the role of deep learning and computer vision techniques in enabling scalable and reliable validation of activities such as cleanup, plantation, recycling, and eco-friendly transportation, and discussed the importance of combining verification mechanisms with incentive-based engagement systems. The survey also highlighted key challenges, research gaps, and future directions, emphasizing the potential of AI-driven platforms to support large-scale, transparent, and trustworthy environmental sustainability initiatives.

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