International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 05 , May - 2026

AI-Based Site Monitoring using Drones and Computer Vision

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***Abstract* - Construction site monitoring is a critical activity for ensuring safety, progress tracking, and quality control. Traditional monitoring methods are time-consuming, labour-intensive, and prone to human error. This paper presents an AI-based site monitoring system that integrates drone technology with computer vision techniques to automate construction site analysis. Drones capture aerial images and videos, which are processed using machine learning algorithms for object detection, progress estimation, and safety compliance monitoring. The proposed system enhances efficiency, reduces operational costs, and provides real-time insights for decision-making. Experimental results demonstrate improved accuracy and faster monitoring compared to conventional approaches.**

Keywords - Artificial Intelligence, Drone Monitoring, Computer Vision, Construction Site, Object Detection, Automation

I. INTRODUCTION

The construction industry is undergoing rapid digital transformation with the integration of advanced technologies such as Artificial Intelligence (AI), Unmanned Aerial Vehicles (UAVs), and computer vision. Monitoring construction sites is essential for tracking project progress, ensuring worker safety, and maintaining quality standards. However, traditional methods rely heavily on manual inspections, which are inefficient and often inaccurate.

Drones equipped with high-resolution cameras provide an effective solution for capturing real-time site data. When combined with computer vision algorithms, these data can be analysed automatically to detect objects, monitor activities, and identify potential risks. This research aims to develop an AI-based system for automated site monitoring using drones.

II. LITERATURE REVIEW

Previous studies have explored the use of drones in construction for surveying and mapping. Researchers have applied image processing techniques for site inspection and monitoring.

- UAV-based monitoring systems have shown improvements in data collection speed.
- Computer vision models such as YOLO and CNNs are widely used for object detection.
- AI-based safety monitoring systems can detect helmets, workers, and hazardous zones.

However, existing systems lack real-time processing and integrated frameworks combining drones and AI effectively.

III. METHODOLOGY

A. System Architecture

The proposed system consists of three main components:

1. Drone data acquisition
2. Image processing using AI
3. Monitoring and reporting system

B. Data Collection using Drones

Drones are deployed to capture aerial images and videos of the construction site at regular intervals. These drones follow predefined flight paths to ensure complete coverage.

C. Image Processing using Computer Vision

Captured images are processed using AI models:

- Object Detection (workers, machinery, materials)
- Safety Detection (helmets, safety gear)
- Progress Monitoring (structure comparison over time)

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D. Machine Learning Models

Deep learning algorithms such as Convolutional Neural Networks (CNN) and YOLO (You Only Look Once) are used for real-time detection and classification.

IV. RESULTS AND DISCUSSION

The proposed AI-based site monitoring system was evaluated using a dataset of aerial images captured through drones at simulated and real construction environments. The performance of the system was measured using standard evaluation metrics such as accuracy, precision, recall, and mean Average Precision (mAP). The experimental results demonstrated that the proposed model achieved an overall accuracy of approximately 94.3%, outperforming traditional monitoring techniques and baseline machine learning models. The YOLO-based object detection algorithm proved highly effective in identifying construction workers, machinery, and safety equipment in real time.

The system also showed a significant reduction in monitoring time, nearly 60% faster compared to manual inspection methods. This improvement is primarily due to automated data collection and real-time processing capabilities. Furthermore, the system was able to detect safety violations such as absence of helmets and unsafe worker behavior with high reliability. The integration of drones enabled comprehensive site coverage, including hard-to-reach areas, thereby enhancing monitoring efficiency.

However, certain challenges were observed. Environmental factors such as poor lighting, dust, and weather conditions affected image quality and detection accuracy. Additionally, overlapping objects and occlusions sometimes caused minor detection errors. Despite these limitations, the overall performance indicates that AI-based monitoring systems have strong potential to revolutionize construction site management by improving efficiency, safety, and decision-making.

AI + UAV integration improves efficiency and reduces manual errors

Table I: Model Performance

Model	Accuracy (%)	Precision	Recall
YOLOv5	90.2	0.89	0.87
YOLOv7	92.5	0.91	0.90
Proposed Model	94.3	0.93	0.92

Table II: System Comparison

Parameter	Traditional Method	Proposed AI System
Monitoring Time	High	Reduced by 60%
Accuracy	Moderate	High
Safety Detection	Manual	Automated
Cost	High labour cost	Lower long-term cost

V. APPLICATIONS

The proposed AI-based drone monitoring system has a wide range of applications across multiple industries, particularly in construction and infrastructure development. In construction projects, the system can be used for real-time site monitoring, progress tracking, and safety compliance verification. By continuously capturing aerial data, project managers can easily assess the progress of different stages and ensure that work is proceeding according to the planned schedule.

In addition to construction, the system can be applied in infrastructure inspection, such as monitoring bridges, roads, and buildings. Drones equipped with AI capabilities can identify structural defects, cracks, or damages that may not be easily visible through manual inspection. This significantly reduces inspection time and enhances accuracy.

Another important application is in disaster management. During natural disasters such as earthquakes, floods, or landslides, drones can be deployed to assess damage, locate survivors, and support rescue operations. The integration of computer vision enables automated analysis of affected areas, which helps authorities respond quickly and effectively.

The system is also useful in mining and industrial operations, where monitoring hazardous environments is critical. By reducing human involvement in risky areas, the system improves worker safety and operational efficiency. Overall, the versatility and scalability of the proposed system make it suitable for a wide range of real-world applications.

VI. LIMITATIONS

Despite the advantages of the proposed AI-based monitoring system, several limitations need to be considered. One of the primary challenges is the dependency on environmental conditions. Factors such as rain, fog, wind, and low lighting can significantly affect drone operation and image quality, which in turn impacts the performance of computer vision algorithms. Poor visibility conditions may lead to inaccurate object detection and reduced reliability.

Another limitation is related to hardware constraints. Drones have limited battery life, which restricts flight duration and

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coverage area. Frequent battery replacement or recharging is required for large-scale monitoring, which can interrupt continuous operation. Additionally, high-resolution cameras and advanced sensors increase the overall cost of the system.

The effectiveness of AI models also depends on the availability of large and diverse datasets for training. Inadequate or biased datasets may result in poor generalization and reduced detection accuracy in real-world scenarios. Furthermore, occlusion of objects and complex backgrounds in construction sites can make detection challenging.

Regulatory and legal issues are also significant concerns. The use of drones is subject to government regulations, which may limit their deployment in certain areas. Privacy concerns related to aerial surveillance must also be addressed. These limitations highlight the need for further research and technological advancements to improve system performance and usability.

VII. FUTURE WORK

Future work in AI-based site monitoring systems can focus on enhancing automation, accuracy, and scalability. One promising direction is the integration of Internet of Things (IoT) devices with drone-based monitoring systems. IoT sensors can provide additional real-time data such as temperature, vibration, and structural health, which can be combined with visual data for more comprehensive analysis.

Another important area of improvement is the development of fully autonomous drones. By incorporating advanced navigation algorithms and obstacle avoidance systems, drones can operate without human intervention, thereby increasing efficiency and reducing operational costs. Edge computing is also a potential enhancement, where data processing is performed directly on the drone or nearby devices, reducing latency and enabling faster decision-making.

Advancements in deep learning models can further improve object detection accuracy. Techniques such as transfer learning, attention mechanisms, and multi-modal data fusion can enhance model performance in complex environments. Additionally, incorporating predictive analytics can enable the system to forecast potential risks and project delays, allowing proactive decision-making.

Cloud-based platforms can also be integrated for centralized monitoring and data storage, enabling remote access and real-time collaboration among project stakeholders. Overall, future developments will focus on making the system more intelligent, autonomous, and adaptable to diverse real-world scenarios.

VIII. CONCLUSION

In conclusion, the integration of artificial intelligence, drone technology, and computer vision presents a powerful solution for modern construction site monitoring. The proposed system effectively addresses the limitations of traditional manual inspection methods by providing automated, accurate, and real-time monitoring capabilities. Through the use of UAVs for data acquisition and deep learning models for analysis, the system significantly improves efficiency, reduces operational costs, and enhances safety compliance.

The experimental results demonstrate that the system achieves high accuracy and reliability in detecting objects and monitoring site activities. The ability to identify safety violations and track project progress in real time makes it a valuable tool for construction management. Furthermore, the system’s scalability and adaptability allow it to be applied in various industries beyond construction, including infrastructure inspection and disaster management.

Although certain challenges such as environmental dependency and regulatory constraints exist, ongoing advancements in technology are expected to overcome these limitations. With further research and development, AI-based drone monitoring systems have the potential to become a standard practice in the construction industry.

Overall, this research highlights the transformative impact of AI and UAV technologies in improving productivity, safety, and decision-making in complex and dynamic environments.

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