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Exploration of UAVs in the Field of Smart Construction

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Abstract: The construction industry is one of the largest sectors in the world. However, traditional construction remains labor-intensive and currently faces numerous challenges, including project delays, poor quality, and management complexity. As a result, there is a rapidly growing demand for digitization and intelligent transformation within the industry. This paper aims to provide an overview of the current utilization and future prospects of UAVs in smart construction. With the advancement of new technologies (wireless communication, high-capacity batteries, and intelligent algorithms), drones are increasingly demonstrating their high-performance capabilities, diverse categories, and versatile applications, and have already made significant inroads in intelligent construction. Based on recent research and developments, this paper explores the applications, challenges, and safety concerns associated with UAVs. A comprehensive discussion is conducted on UAV classifications, current research status, and their applications in popular fields such as smart construction sites and intelligent operation and maintenance (O&M). Finally, research gaps are identified, and future research directions for UAVs are proposed.

Keywords: UAV, Smart construction, Intelligent operation and maintenance (O&M).

1. Introduction

As one of the world's largest industries, the construction sector is among the least digitized industries [1]. Low levels of digitization often lead to challenges such as project delays, poor quality, and complex management issues [2]. With technological advancements, the construction industry is now exploring innovative digital technologies to address these problems, including Building Information Modeling (BIM), Artificial Intelligence (AI), the Internet of Things (IoT), and unmanned robotic technologies. This has led to the emergence of a new field—smart construction.

At present, smart construction has gained considerable attention from both academia and the construction industry. According to a statistical study by Zhang et al. [3], smart construction has been a hot topic since 2008, and its popularity is expected to continue growing for a long time.

Since smart construction lacks a precise definition, it can be considered a system that integrates software, hardware, wireless sensors, and computing units to enable data-driven and automated construction processes [3]. Notably, smart construction is not solely focused on economic benefits, as is traditionally the case in the construction industry; instead, it places greater emphasis on social benefits and the industry's sustainable development [3]. As a result, various aspects of smart construction are rapidly evolving.

Among them, UAVs, studied extensively by Syed Agha et al. [4], have demonstrated high maneuverability, cost efficiency, and stability, making them widely used in military, construction,

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surveying, and aerial surveillance applications. In summary, this paper aims to conduct a rigorous review and analysis of UAV applications in smart construction, striving to provide a coherent and comprehensive perspective on UAV technology in this field. This will serve as a guide for technological advancements and innovation in smart construction. Specifically, this study seeks to answer the following three questions: (1) What is the current state of research on UAVs in the global smart construction industry? (2) What are the most efficient ways to use UAVs in smart construction? (3) What are the existing research challenges and future research directions in this field? To answer these questions, this study adopts an information analysis method aimed at summarizing representative research papers in this field.

2. Current Status of UAVs

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, are autonomous or remotely controlled aircraft. Figure 1 illustrates a typical UAV system architecture, demonstrating how UAVs interact with satellites, ground control systems (GCS), smartphones, and computers through communication links. Compared to manned alternatives with similar payload capacities, UAVs offer greater cost-effectiveness and the ability to perform autonomous tasks in environments that are challenging or hazardous for human intervention.

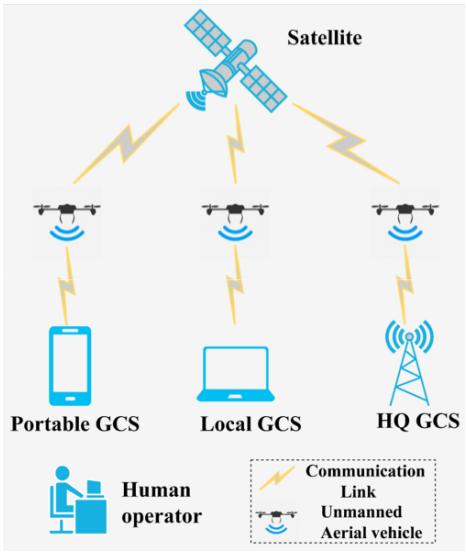

Figure 1: UAV System Architecture [4]

2.1. Types of UAVs

Different UAV types are employed depending on the specific use case. Table 1shows the number of rotors or propellers varies across different UAV models available in the market. In this study, UAVs are categorized into four types: fixed-wing, hybrid fixed-wing, single-rotor, and multi-rotor UAVs, as detailed in Table 2.

Table 1: UAV Classification Based on the Number of Propellers

UAV Type	Number of Propellers
Octocopter	8
Hexacopter	6
Quadcopter	4
Tricopter	3

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Table 2: Key Characteristics of Different UAV Categories

UAV Type	Key Characteristics
Fixed-Wing	High speed, long endurance
Hybrid Fixed-Wing	Long endurance, vertical takeoff capability
Single-Rotor	Long endurance, hovering ability, vertical takeoff capability
Multi-Rotor	Short endurance, hovering ability, vertical takeoff capability

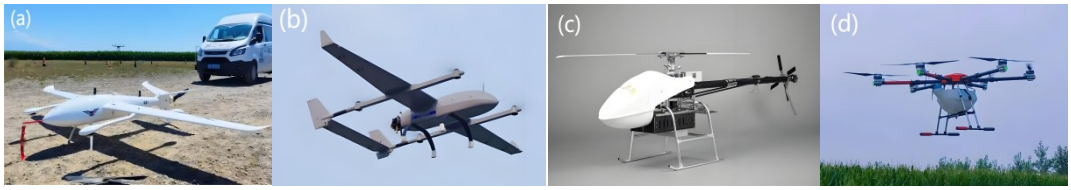

Figure 2: (a) Fixed-Wing UAV, (b) Hybrid Fixed-Wing UAV, (c) Single-Rotor UAV, (d) Multi-Rotor UAV

2.2. Relevant Research

As a rapidly emerging field, UAV technology has attracted extensive research interest. Based on their research focus, studies in this domain can be broadly categorized into two types: UAV technology research (hardware and software development) and interdisciplinary UAV applications (integration with other disciplines).

2.2.1. UAV Technology Research

This category focuses on the UAV itself, with research areas primarily covering battery (charging) technology and communication systems. For example, [4] discusses a mobile charging technology designed to extend UAV battery life, while Lu et al. [5] propose various wired and wireless energy transmission techniques to improve UAV flight duration. Additionally, laser power transmission (LPT), which is primarily used in space and military applications, is also explored in [4].

2.2.2. Interdisciplinary UAV Applications

This category encompasses research that integrates UAVs as platforms within various disciplines. UAVs are typically employed as tools in these studies rather than as the primary research subject. For instance, Hua Li [6] utilizes UAVs equipped with machine vision algorithms to conduct safety inspections of high-altitude edge work environments. Similarly, Colomina [7] discusses the latest advancements and applications of UAVs in photogrammetry and remote sensing. Furthermore, UAVs have been extensively studied and applied in transportation, logistics, and military sectors. Notable examples include China's autonomous UAV air taxi “EHang 184” and UPS’s electric UAV-based doorstep delivery service.

3. UAV in Intelligent Construction

3.1. Smart Construction Sites

Intelligent construction transforms traditional labor-intensive construction sites into data-driven environments, enhancing the level of digitization, interconnectivity, and intelligence in on-site construction management [4]. Specifically, it improves the interaction between workers, machinery,

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building components, and the environment, thereby increasing decision-making efficiency. Compared to conventional methods, UAVs not only reduce the need for human labor and enable 24/7, comprehensive supervision but also enhance process transparency and safety while optimizing the use of construction tools and materials. Figure 3 presents a framework for establishing a smart construction site [4], including the information and communication system, integrated robotic system and safety management system.

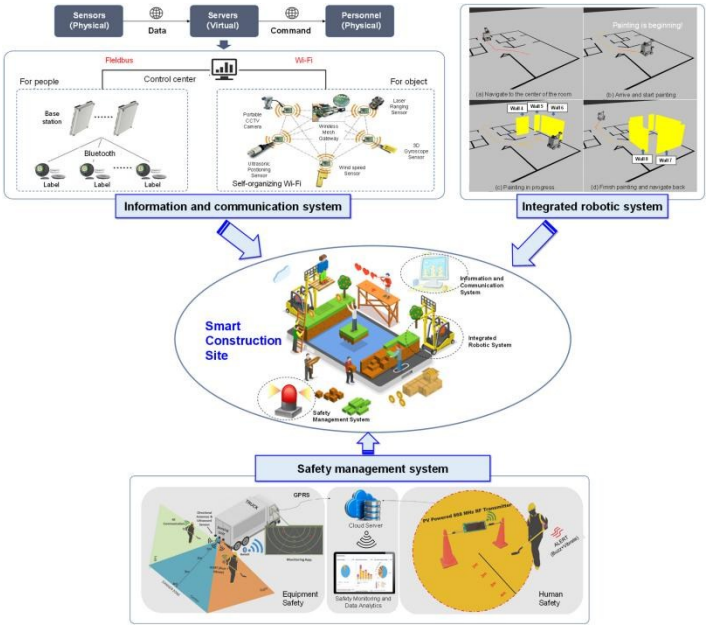

Figure 3: Framework of a Smart Construction Site [3]

From an economic perspective, UAVs reduce project timelines, accelerate capital turnover, and minimize risks. Numerous researchers, including Young et al. [8], have studied UAV-based earthwork surveying to simplify workloads and speed up construction progress. Juliana et al. [9] applied UAVs and 3D reconstruction technology for surveying and mapping tasks. UAVs also help lower labor costs—for example, Xu Zhang [10] used UAVs to replace manual tower crane inspections and provided a detailed cost comparison between the two methods. To address the challenges of manual project management, Javier [11] explored UAV applications in construction task management. From a sustainability standpoint, UAVs play a crucial role in safety inspections and environmental monitoring on construction sites. According to Chile's Social Security Supervision Bureau, each safety incident results in an average loss of 23.4 workdays [3], and the accident rate can increase by 40% without proper safety planning [3]. To mitigate such risks, Alizadehsalehi et al. integrated Building Information Modeling (BIM) with UAVs to detect hazardous conditions and conduct real-time site monitoring. UAVs can be used to identify safety issues such as:

- Missing guardrails
- Insufficient safety signage
- Scaffolding hazards
- Unprotected floor openings
- Workers not wearing proper Personal Protective Equipment (PPE)
- Improper disposal of hazardous waste [12]

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3.2. Smart Operation and Maintenance (O&M)

The operation and maintenance (O&M) phase is considered the longest stage in a building's lifecycle, involving multiple stakeholders, facilities, professionals, and complex management activities [3]. The advancements in sensors, IoT devices, and BIM platforms have further facilitated the development of intelligent O&M ecosystems [13]. Figure 4[3] illustrates the technical architecture and application scenarios of an Intelligent Infrastructure Management System. Core components include machine learning (input layer, hidden layers, output layer) integrated with BIM, IoT, and blockchain (data security and traceability) to enable intelligent operation and maintenance (e.g., predictive maintenance) and technological innovation (e.g., automated decision-making) for infrastructure such as buildings, bridges, and roads.

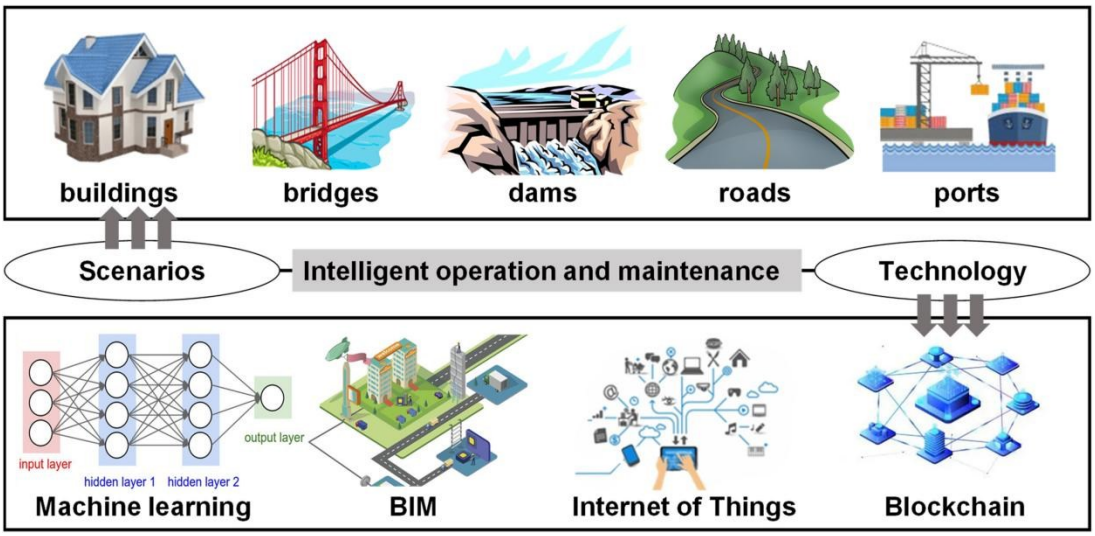

Figure 4: Key Components of Smart O&M [3]

As a multi-sensor integration platform, UAVs play a significant role in smart O&M. The most common application is using UAVs as inspection tools for bridges, roads, power transmission lines, and construction site safety monitoring, as discussed in the previous section. From an economic perspective, UAVs significantly reduce inspection time and costs. Tezel et al. utilized UAVs to capture visual data, which proved to be more time-efficient and cost-effective than manual data collection [14]. Junwon et al. conducted practical bridge inspections using DJI drones [15]. Chuanyang Liu et al. employed UAVs equipped with machine vision algorithms for power grid inspections [16]. From a sustainability perspective, UAVs are also useful in building quality assessment and environmental management. Amir implemented the BIM-UAV method for quality control in construction [17]. Beyond these two major applications, UAVs have expanded into various emerging fields, including smart cities, digital design & automation, intelligent buildings, and smart services. For instance, UAVs are being used in drone delivery services, autonomous aerial taxis, and other next-generation urban mobility solutions.

4. Discussion

In summary, UAVs are expected to play a crucial role in the future, primarily due to their irreplaceable aerial capabilities. Based on the classifications discussed earlier, despite the vast potential of UAVs, there remain significant challenges in both UAV technology development and interdisciplinary applications.

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In UAV technology research, the primary challenges lie in battery endurance and communication systems. These two aspects are fundamental to UAVs, determining their operational limits. In the future, UAV applications will inevitably involve IoT-integrated UAV swarms [4] that require extended flight durations. For interdisciplinary UAV applications, the major challenge is safety. Currently, there are no standardized UAV regulations across different countries. Research [18] has already pointed out that as UAV usage increases, the number of UAV-related accidents is also likely to rise. Since UAVs primarily operate at high altitudes, safety risks remain a significant concern.

To address these issues, several research areas are currently gaining momentum, including:

- Battery material technologies
- Innovative antenna design
- Mobility models
- Machine learning and deep learning algorithms

The first two focus on UAV hardware advancements, aiming to develop lighter and more efficient batteries as well as compact, low-power, and aerodynamically optimized antennas (e.g., Wireless Power Transfer (WPT) technology). The latter areas concentrate on algorithmic improvements, playing a key role in UAV battery scheduling, trajectory planning, tracking, obstacle avoidance, and resource allocation. The advancement of machine learning tools and onboard computing power will facilitate the development of smarter and more compact UAVs, enabling them to perform numerous complex operations without the risk of collisions. Additionally, blockchain technology and computer vision algorithms can further enhance UAV information security and operational capabilities.

5. Conclusion

This paper provides a comprehensive review of recent UAV applications in the field of smart construction from both industrial and academic perspectives. It discusses UAV classifications, current research trends, and their applications in key areas such as smart construction sites and intelligent operation and maintenance (O&M). In conclusion, the construction industry is undergoing a digital transformation, with smart construction receiving significant investment and attention. With their high performance, diverse functionalities, and versatile applications, UAVs have gained widespread adoption across various industries. In particular, UAVs have demonstrated immense potential in areas such as smart construction sites, intelligent O&M, and smart cities. However, despite their growing adoption, UAVs still face technical challenges related to battery endurance, communication systems, and safety concerns. Nevertheless, UAVs are expected to become an indispensable component of smart construction in the near future. Although this paper presents an overview and future outlook on UAV applications in smart construction, the selection of research papers for review may involve subjective factors, and there may be limitations in the discussion and conclusions. Further research is needed to continuously refine and expand the understanding of UAVs in intelligent construction.

References

[1] *Abioye, Sofiat , et al. "Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges." Journal of Building Engineering (2021).*

[2] *Bello, Sururah A. , et al. "Cloud computing in construction industry: Use cases, benefits and challenges." Automation in Construction 122(2020):103441.*

[3] *Zhang, Limao, et al. "Advanced informatic technologies for intelligent construction: A review." Engineering Applications of Artificial Intelligence 137 (2024): 109104.*

[4] *Mohsan, Syed Agha Hassnain, Muhammad Asghar Khan, Fazal Noor, Insaf Ullah, and Mohammed H. Alsharif. 2022. "Towards the Unmanned Aerial Vehicles (UAVs): A Comprehensive Review" Drones 6, no. 6: 147. https://doi.org/10.3390/drones6060147*

DOI: 10.54254/2755-2721/144/2025.21964

[5] Lu, Maxim, et al. "Wireless charging techniques for UAVs: A review, reconceptualization, and extension." IEEE access 6 (2018): 29865-29884.
[6] Li Hua, et al. "Safety Inspection for High-altitude Edge Operations Based on Computer Vision." China Safety Science Journal 33(9) (2023): 69-75. doi:10.16265/j.cnki.issn1003-3033.2023.09.0202.
[7] Colomina, I. , and P. Molina . "Unmanned aerial systems for photogrammetry and remote sensing: A review - ScienceDirect." ISPRS Journal of Photogrammetry and Remote Sensing 92.2(2014):79-97.
[8] Kim, Young Hyun, et al. "Field applicability of earthwork volume calculations using unmanned aerial vehicle." Sustainability 14.15 (2022): 9331.
[9] Juliana, et al. "Exploratory study of using unmanned aerial system imagery for construction site 3D mapping." Construction Innovation Information Process Management (2018).
[10] Zhang Xu. "Application of UAV Safety Inspection Technology in Tower Cranes: A Case Study of the Xiamen Special Zone Jiawan B1-2 Plot Project." Fujian Architecture 9 (2019): 4.
[11] Irizarry, Javier, and Dayana Bastos Costa. "Exploratory study of potential applications of unmanned aerial systems for construction management tasks." Journal of Management in Engineering 32.3 (2016): 05016001.
[12] Alizadehsalehi, Sepehr , et al. "The effectiveness of an integrated BIM/UAV model in managing safety on construction sites." International Journal of Occupational Safety & Ergonomics Jose (2018).
[13] Heaton, Kumar Schooling, Jennifer . "Design and development of BIM models to support operations and maintenance." Computers in Industry 111(2019).
[14] Tezel, Algan , and Z. Aziz . "From Conventional to IT Based Visual Management:A Conceptual Discussion for Lean Construction." Electronic Journal of Information Technology in Construction 12(2017).
[15] Seo, Junwon , L. Duque , and J. Wacker . "Drone-enabled bridge inspection methodology and application." Automation in Construction 94.OCT.(2018):112-126.
[16] Liu Chuanyang, wu is a whole, and jing-jing liu. "the depth of the uav aerial image of insulator defect detection study method is reviewed." journal of electrotechnics 1-21. Doi: 10.19595 / j.carol carroll nki. 1000-6753. The tces. 240610.
[17] Faraji, Amir, et al. "Quality management framework for housing construction in a design-build project delivery system: a BIM-UAV approach." Buildings 12.5 (2022): 554.
[18] Moud, Hashem Izadi , et al. "Quantitative Assessment of Proximity Risks Associated with Unmanned Aerial Vehicles in Construction." Journal of Management in Engineering 37.1(2020).