# Research on the Application of Total Stations and Drones in Urban Building Surveying

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***Abstract**: With the continuous development of urban construction, traditional building surveying methods have gradually revealed their limitations in complex environments, such as insufficient measurement accuracy and efficiency. As two important surveying tools, total stations and drones each have unique advantages. A total station provides high-precision ground point measurements, while drones can quickly capture large-scale spatial data. By combining the two through data sharing and collaborative operation, the accuracy and efficiency of urban building surveying can be effectively improved. This study explores the integration of total station and drone technology in urban building surveying, proposes the process and methods of technical implementation, analyzes the challenges of precision control and data fusion, and discusses future development directions in intelligent and automated surveying technologies.*

***Keywords:** Total station, Drone, Urban building surveying, Data fusion, Precision control, Automation*

## Introduction

In modern urban construction, building surveying is a critical step, and traditional methods face increasing challenges in terms of efficiency and accuracy. With the advancement of technology, total stations and drones have become important tools in the surveying field, especially in complex urban environments, where they provide higher measurement accuracy and broader data collection capabilities. Total stations, with their high precision and reliability, are widely used in ground measurements of buildings, while drones can quickly capture large-scale 3D image data. The combination of these two tools not only improves the surveying efficiency but also overcomes the limitations of a single device in complex environments. Therefore, exploring the integration of total stations and drones, along with their application in urban building surveying, holds significant theoretical and practical importance.

## 1. Overview of Total Station and Drone Technologies

### *1.1 Development and Application of Total Station Technology*

A total station is a modern surveying instrument that integrates optical measurement, electronic data processing, and computer technology. It is widely used in fields such as construction, engineering, geographic information systems (GIS), and land surveying. Since the introduction of the first total station in the late 1970s, the technology has evolved from mechanical to electronic, and it has gradually developed towards intelligence and multi-functionality. Initially, total stations relied on optical telescopes to observe targets, determining object positions by measuring angles and distances. With technological advancements, modern total stations are equipped with advanced electronic systems capable of precise angle and distance measurements. These instruments, aided by computer technology, not only process and store data in real-time but can also transmit data directly to remote systems via wireless communication, significantly improving work efficiency and measurement accuracy. Furthermore, the integrated design of modern total stations makes them more portable and flexible, adapting to complex and changing surveying environments.[1]
In practice, total stations are widely used in building and engineering surveying. Particularly in urban building surveys, due to their high precision and efficiency, they are essential for tasks such as topographic surveys, building location, structural monitoring, and construction control. When

conducting tasks, total stations effectively improve data collection efficiency and ensure the reliability of measurement results. However, despite the significant advantages in accuracy and operational efficiency, total stations still face some limitations, especially in urban building surveying. First, their measurement coverage is relatively small, making them unsuitable for large-scale surveying tasks. Second, the operator's dependence on the instrument and the limitations in measurement accuracy in complex terrain conditions are challenges. Therefore, improving the intelligence and adaptability of total stations has become an important direction in the development of surveying technology.

### *1.2 Principles and Development of Drone Technology*

The rapid development of drone (Unmanned Aerial Vehicle, UAV) technology, especially its application in aerial photography and remote sensing, has greatly accelerated innovation in surveying technology. A drone is a flying device that operates without a pilot, completing tasks through remote control or autonomous flight systems. Its core technologies include flight control systems, automatic navigation systems, and various sensor systems such as high-precision GPS, LiDAR (Light Detection and Ranging), and high-definition cameras. The flight stability, data acquisition capability, and autonomy of drones give them significant advantages in geographic spatial data collection.[2]

Initially used for military purposes, drone technology has expanded to many civilian sectors, particularly in urban building surveying, where it offers broad perspectives and efficient data collection capabilities. Equipped with high-definition cameras, drones can quickly capture large-scale, high-resolution imaging data, providing reliable information for 3D modeling, topographic map creation, and structural analysis of buildings. Furthermore, as drone technology continues to mature, with longer flight times, faster data transmission speeds, and improved measurement accuracy, their application in complex urban environments is becoming increasingly recognized.

### *1.3 Theoretical Basis for Combining Total Stations and Drones*

The combination of total stations and drones offers a more efficient and precise solution for urban building surveying. This integration is based on the collaborative working principle of modern surveying. Drones capture large-scale, high-resolution spatial data, while total stations perform precise ground point measurements. Together, they enable more accurate 3D modeling and geographic spatial data collection. Each tool has its own advantages: the total station provides high-precision point measurements, while the drone can efficiently and quickly complete large-scale aerial surveying tasks. When combined, these tools complement each other and overcome the limitations that may arise when using them individually.

Theoretically, the core of the total station and drone integration lies in the effective fusion and precision matching of their data. The image data captured by drones and the ground control points measured by total stations are integrated and synchronized through a Geographic Information System (GIS) platform. This integration allows large-scale and precise building surveying tasks to be completed in a shorter time. This process is not merely a simple technological overlay but represents an innovative fusion in spatial data management, precision optimization, and operational efficiency. Based on this theoretical framework, urban building surveying is gradually becoming more intelligent and automated. As technology continues to develop, the application of total stations and drones will play an even greater role in various surveying tasks.

## 2. Technical Implementation of Combining Total Stations and Drones

### *2.1 Surveying Task Planning and Organization*

In urban building surveying, the combination of total stations and drones requires detailed planning and proper organization of the surveying tasks to ensure both the efficiency and accuracy of data collection. First, the task planning should be based on the project requirements, terrain characteristics, building scale, and measurement accuracy requirements. For more complex urban environments, factors such as building density, terrain undulation, and elevation differences should be considered to ensure that the surveying plan is adaptable and flexible.[3]

During the planning phase, a site survey should be conducted to determine the survey area and key measurement points. Based on the characteristics of the survey area, suitable drone flight paths and total station measurement point layouts should be selected. For the drone component, flight parameters such as altitude, speed, and overlap should be properly planned to ensure that the image overlap and resolution meet the requirements for subsequent processing. For the total station component, the most appropriate measurement points should be identified according to the building's location and shape to ensure that the control points captured by the total station can cover the entire survey area as comprehensively as possible. In task organization, coordination between the drone and total station's work schedule and operating procedures is essential to avoid conflicts when both are operating simultaneously, thereby improving work efficiency and ensuring data reliability.

### *2.2 Data Collection and Processing Workflow*

Data collection and processing are critical stages in the application of combining total stations and drones, directly affecting measurement accuracy and data utility. During data collection, the drone uses its flight stability and high-precision GPS system to capture aerial images of the building and surrounding environment. The flight task should ensure that the image overlap meets the required standards for subsequent image matching and 3D reconstruction. During the flight, the drone's high-resolution camera or LiDAR (Light Detection and Ranging) system can capture rich ground information, laying the foundation for fine data processing.[4]

The total station, on the other hand, measures precise ground control points to gather spatial position data for buildings and surrounding objects. While the total station offers high accuracy, its coverage is limited, which necessitates the effective integration of data collected by the drone. In the data processing stage, the aerial imagery and LiDAR data are first used to generate a point cloud model. Image processing software is then employed for image matching, point cloud registration, and 3D reconstruction. Subsequently, a Geographic Information System (GIS) platform is used to precisely register the control points collected by the total station with the image data captured by the drone, achieving spatial alignment and data fusion. The processed data can then be used for 3D modeling of buildings, detailed measurements, and structural analysis, providing accurate spatial data support.

### *2.3 Precision Analysis and Quality Control*

Precision analysis and quality control are the core steps to ensure the reliability of the combined total station and drone measurement results. Since the total station and drone have different measurement accuracies and error characteristics, effectively managing the sources of errors from both tools and optimizing precision is a major challenge in the technical implementation.

In the measurement process, the precision of the total station is generally high, especially in short-range measurements, where its angular and distance measurement errors are minimal. However, for large-scale measurements, errors may gradually amplify. On the other hand, the measurement accuracy of the drone is influenced by the precision of its sensors, flight altitude, and environmental factors. In particular, in complex terrains or under strong wind and other meteorological conditions, the drone's flight stability and data collection accuracy may be compromised.

Therefore, the primary task in precision control is to ensure the spatial alignment accuracy between the data collected by the total station and the drone. During data fusion, precise mathematical methods such as least squares adjustment and bundle adjustment should be employed to optimize and correct the different data sources, improving the overall measurement accuracy. For the drone data, reverse engineering calibration and ground control point corrections should be applied to ensure the positioning accuracy and matching of high-resolution images during large-scale measurements. Additionally, real-time monitoring of flight status and measurement equipment should be conducted to ensure that the drone and total station work in the best possible coordination. Periodic accuracy checks and data verification are also essential to ensure the final measurement results' reliability.[5]

## 3. Application Prospects of Combining Total Stations and Drones in Urban Building Surveying

### *3.1 Trends in Technological Integration in Urban Building Surveying*

#### *3.1.1 Automation and Intelligent Development*

With the diversification and complexity of urban building surveying demands, the integration of total stations and drones has driven surveying technology towards automation and intelligent development. Drones, as key tools for data acquisition, have become one of the core technologies in modern surveying due to their flexible flight patterns and efficient ground coverage capabilities. On the other hand, total stations ensure data accuracy with their high precision and reliability. This integration has gradually transformed surveying task planning and execution towards automation, especially in aspects such as automatic adjustment of drone flight paths, data collection parameter settings, and total station point layouts. The application of intelligent technologies is continuously enhancing work efficiency and precision while reducing human intervention.

#### *3.1.2 Spatial Data Sharing and Collaborative Applications*

The integration of total stations and drones extends beyond data acquisition to encompass trends in data sharing and collaborative applications. By seamlessly aligning the imagery data collected by drones with the control point data obtained from total stations, urban building surveying is advancing towards data integration and information sharing. Data collection, processing, analysis, and subsequent Building Information Modeling (BIM) construction can achieve more efficient and accurate information flow and collaborative operations. In the future of urban building surveying, cloud computing-based data management and analysis will become mainstream, enabling different devices and technologies to share data resources and provide efficient data support for building design, construction, and maintenance.

#### *3.1.3 Multi-Dimensional Data Acquisition and High-Precision Measurement*

Current urban building surveying not only requires high measurement precision but also demands the effective handling of multi-dimensional data in complex urban environments. The combination of total stations and drones provides technological support for multi-dimensional data collection. Drones can quickly obtain large-scale high-resolution imagery and, through LiDAR (Light Detection and Ranging) technology, achieve fine acquisition of three-dimensional point clouds, while total stations are responsible for the precise measurement of key control points. This fusion of multi-source data not only improves measurement precision but also provides more comprehensive data support for complex urban building structures, particularly in volumetric and high-altitude measurements, demonstrating significant application potential.[6]

### *3.2 Challenges and Technical Difficulties*

#### *3.2.1 Precision Control and Data Fusion*

Although total stations and drones each possess excellent measurement precision, data fusion accuracy becomes a key challenge due to the different sources of errors inherent in each system. The angle and distance measurement errors of total stations may be influenced by environmental factors, while the flight stability, sensor accuracy, and external interference (such as wind speed and weather) of drones can affect the accuracy of data acquisition. In the data fusion process, how to effectively eliminate or reduce the errors from both measurement systems, ensuring global consistency and meeting high precision requirements, remains a significant difficulty in technical implementation.

#### *3.2.2 Flight Safety and Environmental Adaptability*

In urban building surveying, the safety of drone flights and their adaptability to the environment are also critical technical challenges. Particularly in dense urban areas, high-rise buildings, complex terrain, and changing weather conditions may impact the flight stability of drones and the effectiveness of data acquisition. Flight path planning must avoid obstacles while ensuring flight efficiency and accuracy. In narrow and complex spaces, how to reasonably plan the flight path to ensure data integrity and measurement precision remains one of the technical challenges in practical implementation.

#### *3.2.3 Data Processing and Software Compatibility Issues*

Data generated by total stations and drones often come in different formats and require different processing approaches. Effectively handling and integrating data from both devices, while avoiding data loss or distortion, continues to be a challenge. Especially in big data environments, how to efficiently store, process, and rapidly analyze large volumes of measurement data poses a significant test for data processing platforms and algorithms. The operating software for total stations and drones needs to be compatible with multiple formats and enable seamless data integration. Additionally, in real-time data analysis, reducing processing delays while ensuring data quality will be a key aspect of future technological advancements.

### *3.3 Future Directions and Innovative Applications*

#### *3.3.1 Intelligent and Autonomous Measurement Systems*

In the future, the combination of total stations and drones will move towards more intelligent and autonomous systems. As Artificial Intelligence (AI) and machine learning technologies mature, drones will be able to perform more intelligent autonomous flight, path planning, and data acquisition. For example, AI-based visual recognition systems could allow drones to automatically identify building features and dynamically adjust flight paths and capture angles, significantly improving flight efficiency and measurement accuracy. Total stations will also interact with drones in real-time data exchange to achieve automatic precision calibration and task scheduling optimization. This intelligent collaborative system will greatly enhance the precision, efficiency, and automation of urban building surveying, reducing human intervention and errors, and further improving work efficiency and measurement precision.

#### *3.3.2 Deep Integration with Building Information Modeling (BIM)*

With the rapid development of BIM technology, the future of urban building surveying, combining total stations and drones, will see deeper integration with BIM systems. By combining the high-precision control point data from total stations with the three-dimensional point cloud data from drones, accurate digital models can be directly provided for BIM systems. This will not only enhance the precision of building design and construction but also provide real-time data support and dynamic updates throughout the building's lifecycle. This integration will promote the digital management, intelligent monitoring, and maintenance of urban buildings, increasing the overall efficiency and sustainability of the construction industry.

#### *3.3.3 Cloud Computing and Big Data Analytics*

Cloud computing and big data technologies will play an increasingly important role in the integration of total stations and drones in urban building surveying. Through cloud platforms, survey data can be remotely stored, managed, and shared, facilitating collaboration and data flow across different urban projects. In the future, measurement systems based on big data analysis will be able to process data more accurately and perform real-time monitoring, avoiding measurement errors caused by human factors. Furthermore, the mining and analysis of big data will allow urban building surveying to go beyond just data collection, enabling predictive analysis of building structures and providing intelligent decision-making support for urban planning and building maintenance.
Through these innovative applications, the integration of total stations and drones in urban building surveying will continue to elevate technological levels, providing robust data support and technical guarantees for urban construction, management, and intelligent development.

## Conclusion

The integration of total stations and drones has brought revolutionary advancements to urban building surveying, improving both measurement precision and efficiency. However, challenges such as precision control, data fusion, and flight safety remain, especially in complex urban environments. In the future, with the continuous development of automation and intelligent technologies, this combination will play an even larger role in urban building surveying. Specifically, as flight control technologies, data processing platforms, and precision optimization algorithms continue to improve, the measurement technology integrating total stations and drones will mature and play a key role in urban planning, architectural design, and construction monitoring. Furthermore, collaborative platforms based on cloud computing and big data analysis will bring more innovations in data sharing and processing efficiency, further advancing the intelligent and efficient development of urban building surveying.

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