

Drones Revolutionize Crime Scene Documentation And Reconstruction

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Introduction

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have emerged as transformative tools in various fields, including forensic investigations. Their ability to provide an elevated perspective and capture data in ways previously unimaginable has revolutionized crime scene documentation, offering an aerial viewpoint that traditional methods struggle to replicate. This advanced capability allows for rapid acquisition of crucial data across extensive areas, significantly enhancing the efficiency of crime scene processing. Furthermore, drones facilitate the creation of comprehensive three-dimensional models, which are instrumental in the digital reconstruction of crime scenes, providing an immersive and detailed understanding of the spatial relationships present. They can also safely access locations that are hazardous or difficult for human investigators to reach, thereby preserving the integrity of the scene and minimizing the risk of contamination. The integration of sophisticated technologies such as drone-based photogrammetry and LiDAR sensors enables precise spatial measurements and the meticulous mapping of evidence, which are critical for subsequent forensic analysis and effective presentation in court. While the adoption of this technology is accompanied by challenges, including navigating regulatory frameworks, ensuring adequate operator training, and managing substantial data processing requirements, the overarching benefits in terms of improved efficiency, enhanced investigator safety, and superior quality of documentation are undeniable. These advantages position drones as increasingly indispensable assets in the modern forensic investigation toolkit, promising to further refine the accuracy and thoroughness of evidence collection and analysis in the years to come. The evolving capabilities of drone technology, coupled with advancements in data processing and analytical software, continue to expand its potential applications within the forensic sciences, from initial scene surveying to detailed evidence mapping and reconstruction. [1]

The application of drone-based photogrammetry has been specifically explored for its efficacy in crime scene mapping, demonstrating a remarkable ability to generate highly accurate and detailed three-dimensional models. This research underscores the substantial efficiency gains that can be realized when comparing drone methodologies to conventional crime scene documentation techniques, highlighting a significant leap forward in speed and resource utilization. A key benefit identified is the potential for improved preservation of the crime scene itself, as intrusive methods can be minimized through aerial data capture. The findings consistently suggest that the objective and comprehensive record provided by drone technology is superior, offering investigators a more complete picture that aids considerably in the intricate process of reconstructing events and identifying critical pieces of evidence. The ability to create detailed digital twins of scenes allows for extensive analysis without the need for repeated physical access, which can be particularly advantageous in complex or sensitive investigations. As technology advances, the

resolution and accuracy of these drone-generated models are expected to improve further, offering even greater insights into the dynamics of a crime. The integration of AI-powered analytical tools with these 3D models promises to unlock new avenues for evidence discovery and interpretation. The consistent and reproducible nature of drone data collection also contributes to its reliability in legal proceedings. [2]

Investigating the integration of unmanned aerial vehicles (UAVs) with established crime scene investigation techniques reveals a synergistic relationship where drones enhance traditional methods. This examination details how drones can be effectively employed for a range of tasks, including advanced aerial photography, strategic surveillance of incident areas, and the creation of detailed topographic maps, all of which collectively contribute to a more exhaustive and thorough documentation process. The authors emphasize the pronounced advantages in terms of operational speed and accessibility, particularly when dealing with crime scenes that are expansive in size or complex in their layout, presenting unique challenges for ground-based teams. The ability of drones to quickly survey and map large outdoor areas or inaccessible indoor spaces provides an invaluable overview that can guide subsequent investigative actions. The flexibility of drone deployment allows for adaptation to diverse environmental conditions and scene complexities. Furthermore, the data captured can be readily shared among team members, fostering better coordination and decision-making during the investigation. The insights gained from aerial perspectives can help investigators identify patterns and connections that might otherwise be overlooked. The continuous development of drone payload systems, such as high-resolution cameras and thermal sensors, further expands their utility in forensic contexts. [3]

This article delves into the specific use of drones for the meticulous creation of three-dimensional models of crime scenes, primarily through the application of advanced photogrammetric techniques. It strongly emphasizes the exceptional accuracy and remarkable detail that can be achieved with contemporary drone technology, empowering investigators to perform precise measurements and conduct thorough virtual reconstructions of incident locations. The authors elaborate on how these sophisticated digital models serve as invaluable assets, significantly aiding in the detailed analysis of spatial relationships between various pieces of evidence and the surrounding environment. The ability to precisely measure distances, angles, and volumes within the reconstructed scene provides a quantitative foundation for investigative hypotheses. This level of detail can be crucial in determining the trajectory of projectiles, the points of impact, or the sequence of events. The digital nature of these models also facilitates long-term archiving and future reference without degradation of quality. The ongoing improvements in photogrammetry algorithms and processing software are continually enhancing the fidelity and utility of these reconstructions. The integration of these models into virtual reality environments offers new possibilities for immersive crime scene

analysis and expert testimony. [4]

Focusing on the potential of LiDAR-equipped drones, this paper investigates their application in crime scene documentation, with a particular emphasis on their capacity to generate dense point clouds that meticulously capture intricate details of a scene. The authors undertake a comparative analysis, juxtaposing the data acquired through LiDAR technology with that obtained from traditional photogrammetry, and their conclusions highlight LiDAR's superior accuracy in geometric measurements. This advanced technology is also noted for its effectiveness in low-light conditions, thereby enhancing the overall comprehensiveness and reliability of crime scene documentation, especially in challenging lighting scenarios. The ability of LiDAR to penetrate certain materials and capture precise depth information offers unique advantages for certain types of forensic evidence. The resulting point clouds provide a highly accurate spatial reference frame for all evidence within the scene. The development of lighter and more portable LiDAR systems is making this technology increasingly accessible for field deployment. The fusion of LiDAR and photogrammetric data can create even richer and more informative 3D models. The precision offered by LiDAR is particularly beneficial for tasks requiring meticulous measurements, such as bloodstain pattern analysis or ballistics reconstruction. [5]

Investigating the practical integration of unmanned aerial vehicles (UAVs) with conventional crime scene investigation methodologies reveals a growing trend towards a hybrid approach. This study outlines how drones can be strategically deployed for various purposes, including high-altitude aerial photography, detailed surveillance operations, and the generation of precise topographic maps, all of which significantly contribute to a more comprehensive and efficient documentation process. The authors underscore the substantial advantages in terms of operational speed and enhanced accessibility, particularly for crime scenes that are characterized by their large scale or intricate geographical features, presenting unique logistical hurdles for traditional methods. The rapid deployment and surveying capabilities of drones allow for swift initial assessments of vast areas, enabling investigators to prioritize resources and focus on critical zones. This immediate overview can be crucial in time-sensitive investigations. The ability to revisit and re-survey scenes virtually through the captured data also offers flexibility for ongoing analysis. The development of autonomous flight planning software further streamlines the operational deployment of drones in the field. The integration of multiple sensors on a single drone platform can simultaneously capture different types of data, optimizing field operations. [6]

This article comprehensively reviews the recent advancements in drone technology and critically examines their burgeoning application in the capture of forensic evidence. It elaborates on the diverse ways in which drones can be effectively utilized, encompassing not only standard aerial photography but also more specialized applications such as thermal imaging and multispectral analysis, which can reveal evidence not visible to the naked eye. The authors emphasize the significant potential for enhanced scene interpretation, allowing investigators to glean deeper insights from the collected data, and for achieving faster response times, particularly in emergency situations where swift action is paramount. The ability to detect subtle thermal anomalies or spectral signatures can lead to the discovery of concealed evidence, such as buried objects or camouflaged materials. The rapid deployment capabilities of drones can significantly reduce the time it takes to secure and document a crime scene, especially in remote or inaccessible locations. The continuous innovation in sensor technology for drones is expanding the types of evidence that can be detected and documented from the air. The integration of real-time data streaming from drones to command centers allows for immediate situational awareness and coordinated response efforts. [7]

The research presented in this paper specifically addresses the multifaceted challenges and proposes practical solutions pertinent to the successful implementa-

tion of drone technology within the rigorous workflow of forensic investigations. It meticulously covers a broad spectrum of essential aspects, including adherence to complex regulatory compliance requirements, the strategic planning of flight missions, the establishment of robust data acquisition protocols, and a thorough consideration of the ethical implications associated with drone usage. Crucially, the paper underscores the paramount importance of developing and adhering to standardized procedures to ensure the admissibility and reliability of drone-generated evidence within legal proceedings, a critical step for its acceptance in court. Standardization ensures that data collected is consistent, verifiable, and meets legal standards for evidence handling. The development of clear guidelines for data management and chain of custody is essential for maintaining the integrity of drone-based evidence. Ongoing training and certification programs for forensic drone operators are vital to ensure competence and adherence to best practices. The legal frameworks governing drone usage are continually evolving, requiring ongoing attention and adaptation by forensic agencies. Public perception and acceptance of drone use in investigations also play a role in their broader adoption. [8]

The study detailed in this article focuses on the practical application and utility of drones for the meticulous documentation of outdoor crime scenes, placing significant emphasis on their capacity to capture the broader environmental context surrounding an incident. It provides a detailed account of the procedural steps involved in creating orthomosaic maps and three-dimensional models from aerial imagery, outputs that are recognized as being invaluable for subsequent spatial analysis and for clear, impactful presentation within legal proceedings. The authors also candidly address some of the inherent challenges encountered, such as the unpredictable nature of weather conditions and limitations imposed by maintaining a clear line of sight, factors that require careful consideration during mission planning and execution. The ability to generate large-scale, georeferenced maps provides investigators with a comprehensive overview of the area, helping to establish the spatial relationships between various crime scene elements and their surroundings. The creation of detailed 3D models allows for precise measurements and analysis of terrain, vegetation, and other environmental features that may be relevant to the investigation. Addressing weather-related challenges often involves utilizing predictive modeling and having contingency plans for rescheduling or adapting flight operations. Maintaining consistent GPS signals and avoiding obstructions are key considerations for ensuring data accuracy in outdoor environments. The development of more robust and weather-resistant drone platforms is continuously improving operational reliability. [9]

This paper undertakes an in-depth investigation into the accuracy and precision characteristics of drone-based photogrammetry specifically for the purpose of crime scene documentation. It offers a detailed analysis of the various factors that can potentially influence the quality of the captured data, including critical parameters such as camera settings, flight altitude, and the degree of image overlap achieved during the aerial survey. The research findings conclusively demonstrate that, when employing a carefully considered and appropriate methodology, drone-generated three-dimensional models can attain a level of accuracy measured in centimeters, a standard deemed highly suitable for forensic reconstruction purposes and detailed evidence analysis. Achieving centimeter-level accuracy requires meticulous planning of flight paths and adherence to established photogrammetric principles. The quality of the camera's lens and sensor also plays a significant role in the final resolution and accuracy of the 3D model. Post-processing techniques, including the use of ground control points, are essential for refining the accuracy of the generated models. The consistency of results across different drone platforms and software packages is an area of ongoing research and development. Understanding and mitigating sources of error is paramount for ensuring the reliability of forensic reconstructions based on drone data. [10]

This article discusses the critical integration of drone technology into the estab-

lished workflow of forensic investigators, with a particular focus on their inherent ability to rapidly survey and meticulously document large or particularly complex crime scenes. It effectively highlights the significant advantages offered by the utilization of drones, primarily in terms of substantial time savings and the marked reduction of risk to essential personnel, especially when operating within potentially hazardous or dangerous environments. The paper also importantly addresses the recognized need for specialized training programs and the acquisition of appropriate, sophisticated equipment for the truly effective and reliable deployment of drones within specialized forensic contexts. Drones act as force multipliers, allowing smaller teams to cover larger areas more quickly and safely. The ability to conduct initial scene assessments remotely can significantly improve situational awareness and tactical planning. The specialized training required encompasses not only flight operations but also data acquisition protocols, basic maintenance, and understanding the legal framework surrounding drone use in investigations. The cost-effectiveness of drone deployment, when considering the time and personnel savings, is becoming increasingly apparent for law enforcement agencies. The continuous evolution of drone capabilities necessitates ongoing professional development for forensic investigators utilizing this technology. [11]

The integration of Unmanned Aerial Vehicles (UAVs) into forensic investigations represents a significant technological advancement, fundamentally altering how crime scenes are documented and analyzed. Drones offer an unparalleled aerial perspective, enabling rapid data acquisition over large areas and the creation of comprehensive 3D models essential for digital reconstruction [1]. Their ability to access hazardous or difficult-to-reach locations enhances scene integrity and minimizes contamination risks [1]. Photogrammetry and LiDAR technologies, when integrated with drones, provide precise spatial measurements and detailed evidence mapping, crucial for subsequent analysis and courtroom presentation [1, 5]. While regulatory hurdles and operator training present challenges, the benefits in efficiency, safety, and documentation quality are substantial [1, 6, 10]. Drone-based photogrammetry has proven effective in generating accurate 3D crime scene models, offering efficiency gains over traditional methods and improving scene preservation [2]. These technologies provide a more objective and complete record, aiding in event reconstruction and evidence identification [2]. Drones complement traditional techniques by facilitating aerial photography, surveillance, and topographic mapping, particularly for large or complex scenes where speed and accessibility are paramount [3, 8]. The creation of high-resolution 3D models using photogrammetry allows for precise measurements and virtual reconstructions, aiding in the analysis of spatial relationships between evidence and the environment [4]. LiDAR-equipped drones generate dense point clouds with superior accuracy in geometric measurements, even in low-light conditions, enhancing documentation comprehensiveness [5]. Implementing drone technology requires adherence to regulations, strategic flight planning, robust data acquisition protocols, and careful consideration of ethical implications to ensure the admissibility of evidence [6, 8]. Practical aspects of documenting outdoor scenes are enhanced by drones, which capture broader context and create valuable orthomosaic maps and 3D models for analysis and presentation, despite challenges like weather conditions [8]. Accuracy assessments of drone-based photogrammetry reveal that with proper methodology, centimeter-level accuracy is achievable, suitable for forensic reconstruction [9]. Drones act as force multipliers, enabling rapid documentation of large or complex scenes, saving time, and reducing personnel risk in hazardous environments, though specialized training and equipment are necessary [10]. The overall impact of drones in forensic science is characterized by enhanced efficiency, improved data quality, increased safety for investigators, and the potential for more accurate and comprehensive scene reconstructions, solidifying their role as indispensable tools in modern investigations.

Description

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, are revolutionizing crime scene documentation by providing a unique aerial perspective unattainable through conventional methods. Their primary advantage lies in the rapid acquisition of data across vast areas, significantly accelerating the initial phases of scene investigation. Furthermore, drones are instrumental in capturing comprehensive three-dimensional models, which are vital for sophisticated digital reconstruction efforts, allowing for a detailed understanding of the crime scene environment. Their capacity to access hazardous or hard-to-reach locations is a critical safety and integrity measure, minimizing contamination risks and protecting investigators from potential dangers. The synergistic application of drone-based photogrammetry and LiDAR technology empowers forensic professionals with the ability to perform highly precise spatial measurements and conduct meticulous mapping of evidence, which is indispensable for subsequent analytical processes and compelling courtroom presentations. Despite the existence of challenges, including navigating complex regulatory landscapes, the necessity for specialized operator training, and the substantial demands of data processing, the benefits derived from drone utilization in terms of enhanced efficiency, improved investigator safety, and superior quality of documentation are profound. These factors collectively position drones as increasingly indispensable tools in the modern forensic investigation toolkit, promising to further refine the accuracy and thoroughness of evidence collection and analysis. [1]

The specific application of drone-based photogrammetry for crime scene mapping has been extensively studied, highlighting its remarkable capacity to generate highly accurate and detailed three-dimensional models. This area of research consistently emphasizes the significant efficiency gains that can be achieved when drone methodologies are compared against traditional approaches to crime scene documentation, signaling a substantial advancement in speed and resource optimization. A key advantage identified is the improved preservation of the crime scene itself, as the need for intrusive physical methods can be considerably reduced through aerial data capture. The findings from numerous studies strongly indicate that the objective and comprehensive records produced by drone technology offer investigators a more complete and reliable overview, which is profoundly beneficial in the intricate process of reconstructing events and identifying crucial pieces of evidence. The ability to create detailed digital replicas of crime scenes permits extensive analysis without the necessity for repeated physical access, a feature that is particularly advantageous in investigations that are complex or sensitive in nature. [2]

Investigating the seamless integration of Unmanned Aerial Vehicles (UAVs) with established crime scene investigation techniques reveals a powerful synergy where drones significantly augment traditional methodologies. This exploration details how drones can be effectively deployed for a diverse array of critical tasks, including advanced aerial photography, strategic surveillance operations of incident areas, and the meticulous creation of detailed topographic maps. Each of these applications collectively contributes to a more thorough, comprehensive, and efficient documentation process. The authors consistently highlight the pronounced advantages observed in terms of operational speed and enhanced accessibility, particularly when dealing with crime scenes that are characterized by their expansive scale or their complex geographical layout, presenting unique logistical and procedural challenges for ground-based investigative teams. [3]

This article specifically delves into the utility of drones for the meticulous creation of three-dimensional models of crime scenes, employing advanced photogrammetric techniques. It places a strong emphasis on the exceptional accuracy and the remarkable level of detail that can be achieved with contemporary drone technology, thereby empowering investigators to perform precise measurements and conduct

through virtual reconstructions of incident locations. The authors provide an in-depth discussion on how these sophisticated digital models serve as invaluable assets, significantly assisting in the detailed analysis of spatial relationships between various pieces of evidence and the surrounding environment. The precision offered by these models is crucial for understanding the dynamics of an event. [4]

This paper concentrates on the potential offered by LiDAR-equipped drones for crime scene documentation, with a specific focus on their ability to generate dense point clouds that precisely capture intricate details of a scene. The authors engage in a comparative analysis, juxtaposing the data acquired through LiDAR technology with that obtained from traditional photogrammetry. Their findings consistently underscore LiDAR's superior accuracy in geometric measurements and its effectiveness in challenging low-light conditions, thereby enhancing the overall comprehensiveness and reliability of crime scene documentation, especially in scenarios where visibility is limited. [5]

The research presented in this paper thoroughly investigates the practical challenges and proposes viable solutions for the effective implementation of drone technology within the established workflows of forensic investigations. It meticulously addresses a wide array of essential aspects, including strict adherence to complex regulatory compliance requirements, strategic planning of flight missions, the establishment of robust data acquisition protocols, and a comprehensive consideration of the ethical implications associated with the deployment of drones. Significantly, the paper emphasizes the paramount importance of developing and consistently applying standardized procedures to ensure the admissibility and reliability of drone-generated evidence within legal proceedings, a crucial step for its acceptance in judicial contexts. [6]

This article presents a comprehensive review of the recent advancements in drone technology and critically evaluates their increasing application in the capture of forensic evidence. It elaborates on the diverse methods by which drones can be effectively utilized, extending beyond standard aerial photography to encompass more specialized applications such as thermal imaging and multispectral analysis, which have the capability to reveal evidence that might not be visible to the naked eye. The authors highlight the substantial potential for enhanced scene interpretation, enabling investigators to derive deeper insights from the collected data, and for achieving significantly faster response times, particularly in emergency situations where prompt action is of the utmost importance. [7]

The study detailed in this article focuses intently on the practical application and overall utility of drones for the meticulous documentation of outdoor crime scenes, placing a considerable emphasis on their capacity to capture the broader environmental context surrounding an incident. It provides a detailed account of the procedural steps involved in creating high-quality orthomosaic maps and precise three-dimensional models derived from aerial imagery, outputs that are recognized as being exceptionally valuable for subsequent spatial analysis and for clear, impactful presentation within legal proceedings. The authors also candidly discuss some of the inherent challenges encountered during operations, such as the unpredictable nature of weather conditions and limitations imposed by maintaining a clear line of sight, factors that necessitate careful consideration during mission planning and execution. [8]

This paper undertakes an in-depth investigation into the accuracy and precision characteristics of drone-based photogrammetry, specifically tailored for the purpose of crime scene documentation. It offers a detailed analysis of the various critical factors that can potentially influence the quality of the captured data, including parameters such as camera settings, flight altitude, and the degree of image overlap achieved during the aerial survey. The research findings conclusively demonstrate that, when employing a carefully considered and appropriate methodology, drone-generated three-dimensional models can attain a level of accuracy measured in centimeters, a standard deemed highly suitable for forensic

reconstruction purposes and detailed evidence analysis. [9]

This article thoroughly discusses the critical integration of drone technology into the established workflow of forensic investigators, with a particular focus on their inherent ability to rapidly survey and meticulously document large or particularly complex crime scenes. It effectively highlights the significant advantages offered by the utilization of drones, primarily in terms of substantial time savings and the marked reduction of risk to essential personnel, especially when operating within potentially hazardous or dangerous environments. The paper also importantly addresses the recognized need for specialized training programs and the acquisition of appropriate, sophisticated equipment for the truly effective and reliable deployment of drones within specialized forensic contexts. [10]

The integration of drones into forensic investigations offers a paradigm shift in scene documentation. Their ability to rapidly capture high-resolution aerial imagery and create detailed 3D models significantly enhances scene understanding and reconstruction compared to traditional methods. Technologies like photogrammetry and LiDAR, powered by drones, provide precise spatial data crucial for forensic analysis. Despite challenges such as regulations and training, the advantages in efficiency, safety, and data quality are undeniable, making drones essential for modern crime scene investigation.

Conclusion

Drones are revolutionizing crime scene documentation by providing aerial perspectives, rapid data acquisition, and the creation of detailed 3D models for reconstruction. They enable access to hazardous locations, enhance scene integrity, and facilitate precise spatial measurements through photogrammetry and LiDAR. While regulatory and training challenges exist, the benefits in efficiency, safety, and documentation quality are significant. Drone-based photogrammetry offers accurate 3D modeling and efficiency gains, while LiDAR provides superior geometric accuracy. Integrating drones requires standardized procedures for legal admissibility. Drones are valuable for outdoor scene mapping, capturing context, and creating maps for analysis. Achieving centimeter-level accuracy with drone photogrammetry is possible with proper methodology. Drones act as force multipliers, saving time and reducing risk in complex or hazardous scenes, necessitating specialized training. Overall, drones enhance forensic investigations through improved efficiency, data quality, and safety.

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Conflict of Interest

None.

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