GRAND ACADEMIC PORTAL
RESEARCH JOURNALS

GAP INDIAN JOURNAL
OF FORENSICS AND BEHAVIOURAL SCIENCES
(ISSN – 2582-8177)
Globally peer-reviewed and open access journal.

ज्ञानः अध्ययनः परम्परा

DESIGN AND DEVELOPMENT OF A MOBILE 360-DEGREE PHOTOGRAMMETRY SYSTEM FOR CRIME SCENE DOCUMENTATION AND VIRTUAL RECONSTRUCTION

Nitesh C.

Department of Criminology and Forensic Science, St. Philomena's College (Autonomous), Mysuru
nitesh199189@gmail.com; +91 9663790492

Abstract

Properly documenting a crime scene is the backbone of any forensic investigation, as it preserves the exact layout and conditions of the environment for later analysis and courtroom trials. The issue is that traditional photos and sketches fall short of capturing a true 3D space, while high-end laser scanners are far too expensive for most investigative agencies to afford. This study introduces CS360, a mobile-based photogrammetry system built to bridge that gap. By tapping into everyday smartphone features—like GPS, internal sensors, and LiDAR depth tracking—the app actively guides investigators to specific spots to capture a structured series of overlapping images. It then processes these photos to build an interactive, 360-degree digital replica of the scene. Testing shows that CS360 successfully generates accurate, spatially coherent reconstructions. Just as importantly, it ensures the evidence holds up in court by automatically locking in vital metadata, such as exact geographic coordinates, timestamps and the physical orientation of the device. By incorporating a virtual reality (VR) viewing mode, the system allows forensic analysts, lawyers and judges to practically step back into the scene. Ultimately, this provides a highly accessible, immersive tool for analysing evidence, reconstructing events and improving how crime scenes are visualized in the courtroom.

Keywords: - *Crime Scene Documentation, 360-Degree Photogrammetry, GPS, LiDAR Depth Sensing, Virtual Reality Visualization, Evidence Preservation, Smartphone Sensors*

INTRODUCTION

Crime scene documentation is one of the most critical stages in forensic investigation because it preserves the original condition of the scene for analysis and courtroom presentation (Naz, Aien, Fatima, & Ansari, Crime scene to judgment: A review on identifying gaps in crime scene investigation and implementing solutions, 2025). Accurate documentation allows investigators to establish spatial relationships between evidence items and reconstruct events during legal proceedings (Raoof, Yadav, Raj, & Gupta, 2022). Traditional crime scene documentation techniques include photography, sketching, and written notes, which have been widely used in forensic practice for decades (Singh, 2021). However, traditional documentation techniques often fail to preserve the complete three-dimensional spatial relationships present within complex crime scenes (Razali, et al., 2025). Recent technological developments have introduced advanced three-dimensional documentation methods such as laser scanning and photogrammetric reconstruction (Yalçın & Gençay, 2024). Advanced laser scanning systems such as Leica Cyclone FIELD 360 enable investigators to generate highly accurate digital models of crime scenes using point-cloud technology (Cho & Woo, 2025). Despite their advantages, these systems are often expensive and require specialized training, limiting their accessibility for many investigative agencies (Ospina-Bohórquez, et al., 2025). Modern smartphones are now equipped with advanced sensors including GPS receivers, accelerometers, gyroscopes, and LiDAR depth sensors that can support spatial reconstruction of environments (Maiese, Manetti, Ciallella, & Fineschi). The integration of smartphone cameras with photogrammetry algorithms has created opportunities for cost-effective three-dimensional documentation systems in forensic science (Pitts, Wei, Yu, & Rairden, 2020). To address the limitations of traditional documentation methods and expensive scanning technologies, this study proposes CS360, a mobile-based crime scene documentation system that utilizes 360-degree photography, photogrammetry, LiDAR sensing, and GPS-based geolocation to reconstruct crime scenes digitally.

LITERATURE REVIEW

Recent advancements in forensic technology have introduced digital methods such as photogrammetry, laser scanning, and geomatic mapping techniques for documenting crime scenes and reconstructing spatial environments. These techniques allow investigators to capture measurements, angles, and object relationships within the crime scene with greater accuracy compared to traditional manual methods (Naether, Buck, Räss, & Jackowski, 2019). Photogrammetry has become an increasingly important technique in forensic investigations because it allows investigators to generate three-dimensional models of crime scenes using overlapping photographs captured from different perspectives (Jacobsen & Villa, 2019). Three-dimensional crime scene models created through photogrammetry enable investigators to extract measurements, reconstruct environmental geometry, and digitally preserve evidence locations for future examination (Jacobsen & Villa, 2019). In addition to reconstruction technologies, forensic photography remains a fundamental tool for documenting evidence, providing visual records that can be presented during criminal investigations and court proceedings (Ray, 2024). Recent developments have also introduced immersive visualization technologies such as virtual reality, which allow investigators and legal professionals to explore reconstructed crime scenes interactively and analyze spatial relationships more effectively (Zappalà, Guarnera, Rinaldi, Livatino, & Battiato, 2024). Another significant advancement in digital forensic investigation is the use of image metadata such as EXIF data, which records information including the date, time, device type, and geographic coordinates of the captured photograph. This metadata can provide crucial contextual information about when and where an image was taken (Soni, 2025). Geotagged images containing embedded GPS coordinates have been increasingly used in forensic investigations to verify the location of events, confirm timelines, and establish connections between suspects and crime scenes (Peace, 2025). However, several studies have identified limitations in the reliability of digital images when metadata is lost, altered, or removed during image transmission, compression, or social media sharing. Such modifications can affect the integrity and evidential value of digital photographs used in investigations (Soni, 2025). Furthermore, digital images captured on mobile devices can be manipulated or altered using image editing software, raising concerns regarding authenticity and reliability of visual evidence in forensic investigations (Ramos López, Sandoval Orozco, & García Villalba, 2024). Although previous studies have explored photogrammetry, 3D reconstruction, and virtual reality visualization for crime scene documentation, most systems focus primarily on spatial reconstruction without ensuring permanent verification of the original capture location and authenticity of visual evidence. Existing approaches rarely integrate GPS-based geolocation, sensor metadata preservation, and structured capture workflows within a single mobile-based documentation system. Additionally, many reconstruction techniques rely on specialized equipment or complex software environments, limiting their practical adoption in routine forensic investigations. Therefore, there remains a need for a cost-effective mobile-based crime scene documentation system that integrates 360-degree imaging, photogrammetry, LiDAR sensing, and GPS-based metadata preservation to ensure both spatial reconstruction and evidential authenticity of captured visuals. The proposed system CS360 addresses this gap by combining smartphone imaging technologies with sensor-based spatial recording and

METHODOLOGY

System Development Approach
This research follows a design and development methodology to create a mobile-based crime scene documentation system named CS360. The objective of the system is to provide a cost-effective and accessible method for documenting crime scenes using smartphone technologies. The system integrates 360-degree photographic capture, smartphone sensors, GPS geolocation, LiDAR depth sensing, and photogrammetric reconstruction to generate interactive digital representations of crime scenes. The development process focused on creating a structured workflow that allows investigators to systematically capture images while preserving spatial information and contextual metadata. The system was designed to ensure that each captured image is associated with timestamp information, geographic coordinates, and device orientation, which collectively contribute to maintaining the authenticity and integrity of the recorded visual evidence.

System Architecture (SA)
The CS360 system is structured into five primary functional components: Input and Sensor Layer, Scene Capture Module, Image Processing and Reconstruction Module, Visualization Module, Data Storage and Evidence Management Module. The input layer collects data directly from smartphone hardware components including the camera, GPS receiver, accelerometer, gyroscope, and LiDAR sensor (if supported by the device). These sensors provide essential spatial and environmental data required for reconstructing crime scenes. The architecture ensures that visual data captured during scene documentation is synchronized with spatial metadata, enabling the system to reconstruct the scene with accurate orientation and location information.

Crime Scene Capture Workflow
The CS360 application follows a guided documentation workflow designed specifically for forensic investigators. The workflow consists of several sequential stages.

Step 1: Application Initialization
When the application is launched, it requests permissions to access essential device components including: Camera, GPS location, Motion sensors, Device storage, LiDAR sensor (if available). These permissions allow the system to capture images and associated metadata required for scene reconstruction.

Step 2: Case Creation
Investigators begin by creating a new case file within the application. During this stage, the investigator enters basic case information including: Case identification number, Investigator name, Date and time of documentation, Location information. The system automatically records the GPS coordinates of the scene, ensuring that the captured visual evidence is permanently associated with its geographic location.

Step 3: Scene Type Selection

The system supports two primary crime scene categories:

Indoor Crime Scene: - For indoor environments such as rooms or buildings, investigators enter the physical dimensions of the room including: Length, Width, Height. Based on these dimensions, the system generates a virtual floor layout and automatically determines optimal capture positions for image acquisition.

Outdoor Crime Scene: - Outdoor scenes are categorized into two scenarios: Bounded outdoor scene (within walls or structures), Open-field scene with a central object such as a body. For bounded outdoor scenes, the system generates capture points around the perimeter of the area. For open-field scenes, the system creates a circular capture path around the central evidence point to allow complete 360-degree documentation.

Step 4: Guided Image Capture

To ensure sufficient overlap between images for photogrammetric reconstruction, the application generates predefined capture points within the scene. These points appear visually on the device screen as guiding markers that indicate where the investigator should stand during image capture. When the investigator reaches a designated point, the application automatically begins capturing multiple photographs from slightly different angles. Each capture point produces a set of overlapping images that collectively cover the surrounding environment. For indoor environments, capture points are distributed across the room floor area to provide full spatial coverage. For outdoor environments, capture points are arranged in circular or hemispherical patterns around the evidence location.

Step 5: Image Processing and Scene Reconstruction

After image acquisition is completed, the system processes the captured photographs to generate a digital reconstruction of the crime scene. The reconstruction process involves: Feature detection and matching between overlapping images, Camera position estimation, Spatial geometry reconstruction, Image stitching and panoramic generation. These processes collectively produce a 360-degree visual representation of the crime scene that can be explored interactively. If the smartphone supports LiDAR technology, the depth measurements collected from the LiDAR sensor are integrated into the reconstruction process to improve spatial accuracy.

Step 6: Visualization and VR Exploration

Once the reconstruction process is completed, investigators can explore the scene using the application's interactive visualization interface. The interface allows users to rotate, zoom, and navigate through the reconstructed environment. Additionally, the system provides a virtual reality (VR) viewing mode, which enables investigators, lawyers, and judges to experience the reconstructed crime scene immersively. This feature enhances spatial understanding and allows stakeholders to analyse the scene from multiple perspectives.

Step 7: Evidence Annotation and Documentation

The CS360 system also allows investigators to place digital evidence markers within the reconstructed scene. These markers can be used to highlight objects, locations, or areas of interest. Each marker can include: Evidence description, Notes from investigators, Additional images or documentation. This functionality allows investigators to maintain contextual information directly within the reconstructed scene.

Step 8: Data Storage and Case Management

All captured images, sensor metadata, reconstructed scenes, and annotations are stored within a structured case file. The system maintains the following information for each case: Raw photographs, GPS coordinates, Sensor orientation data, Scene reconstruction models, Evidence annotations. These case files can later be exported for further forensic analysis or courtroom presentation.

RESULTS AND DISCUSSION

System Performance and Scene Reconstruction

The CS360 system was designed to enable investigators to document crime scenes using a structured image capture workflow supported by smartphone sensors and photogrammetric reconstruction techniques. During testing, the system successfully captured multiple overlapping images of indoor and outdoor environments and processed them to generate interactive 360-degree visual representations of crime scenes. The guided capture workflow ensured that sufficient overlap was maintained between images, which is essential for accurate photogrammetric reconstruction. The reconstruction process produced spatially coherent visual models that allowed investigators to analyse scene layout, object placement, and environmental context within the reconstructed environment. The integration of GPS geolocation metadata ensured that each captured scene was permanently associated with its geographic location, providing additional evidential value for forensic documentation. Furthermore, the use of smartphone sensor data such as device orientation and timestamp information improved the contextual accuracy of recorded visuals. Compared to traditional crime scene documentation techniques such as static photography and manual sketches, the CS360 system demonstrated improved spatial visualization and documentation capabilities. Investigators were able to revisit the reconstructed scene digitally and observe spatial relationships between evidence items without physically returning to the original location.

User Interface (UI) Design Evaluation

The user interface of CS360 was designed with the objective of providing a simple, structured, and investigator-friendly workflow. Crime scene investigators often work in stressful and time-sensitive environments; therefore, the interface prioritizes clarity, minimal complexity, and quick navigation. The application interface consists of several primary screens including: Permission initialization screen, Case creation interface, Scene type selection screen, Dimension input interface (for indoor scenes), Guided capture interface, Scene reconstruction interface, VR visualization interface. Large buttons, clear visual indicators, and minimal text were used to ensure that investigators could operate the application efficiently in field conditions. The guided capture interface uses visual capture points and directional indicators that guide investigators to specific positions within the scene, ensuring systematic image acquisition. The UI design reduces cognitive load by presenting only the necessary options at each stage of the documentation process. This structured interface design allows investigators to focus on the crime scene itself rather than navigating complex application settings.

User Experience (UX) Evaluation

The user experience of CS360 was evaluated based on usability, workflow efficiency, and ease of learning. The system was designed following a guided workflow model, where investigators are led step-by-step through the crime scene documentation process. One of the most significant UX advantages observed during system testing was the reduction in manual decision-making during image capture. Instead of requiring investigators to determine capture angles manually, the system automatically generates capture points that ensure proper image overlap and scene coverage. The guided capture mechanism significantly improves usability because investigators only need to move to the indicated capture point and allow the system to capture images automatically. This reduces the likelihood of incomplete documentation or missing perspectives. Another important UX feature is the VR visualization mode, which allows investigators to explore reconstructed crime scenes immersively. This feature enhances spatial understanding and allows investigators to examine scene details that may not be easily observable in traditional two-dimensional photographs. Overall, the UX design ensures that investigators with minimal technical training can use the system effectively after a short learning period.

System Architecture (SA) Evaluation

The system architecture of CS360 was designed to integrate smartphone hardware sensors with photogrammetric processing algorithms in a structured and modular framework. The architecture consists of multiple layers including the sensor input layer, image acquisition module, reconstruction module, visualization module, and storage module. The sensor input layer collects data from the smartphone camera, GPS receiver, accelerometer, gyroscope, and LiDAR sensor. These data sources provide essential spatial and contextual information required for scene reconstruction. The image acquisition module manages the guided capture workflow by generating capture points and directing investigators to specific positions within the scene. This module ensures that images are captured with sufficient overlap to support reliable photogrammetric reconstruction.

The reconstruction module processes captured images using feature detection and spatial alignment algorithms to generate the reconstructed scene model. The architecture supports both on-device processing for quick previews and optional cloud-based processing for higher accuracy reconstructions. The modular architecture ensures scalability and allows additional features such as automated evidence detection, AI-based object recognition, and advanced reconstruction algorithms to be integrated in future system versions.

System Design (SD) Evaluation

The overall system design of CS360 was developed with the objective of providing an accessible and cost-effective alternative to high-end crime scene scanning technologies. Traditional laser scanning systems such as Leica FIELD 360 require expensive equipment and specialized training. In contrast, the CS360 system leverages commonly available smartphone hardware to achieve similar documentation capabilities. The structured design of the application ensures that investigators can document crime scenes using a repeatable and standardized process. The integration of room dimension input for indoor scenes allows the system to generate scaled reconstruction environments, improving measurement accuracy. For outdoor scenes, the system dynamically generates capture points around the central evidence location, enabling investigators to document the scene from multiple viewpoints and produce a comprehensive visual representation. The inclusion of GPS metadata recording also strengthens evidential reliability by linking captured visuals to their geographic origin. This feature helps ensure that the visual documentation can be verified and referenced during later stages of investigation and legal proceedings.

Cost and Accessibility Advantages

One of the most significant advantages of the CS360 system is its cost efficiency compared to traditional crime scene scanning technologies. High-end laser scanning systems can cost tens of thousands of dollars, making them inaccessible to many investigative agencies. In contrast, the CS360 system operates using standard smartphones that investigators already carry as part of their equipment. This significantly reduces implementation costs while still providing advanced scene documentation capabilities. Additionally, the simple user interface and guided workflow reduce the need for extensive training. Investigators can learn to operate the system within a short period, enabling rapid deployment in real investigative scenarios.

Research contribution

This research contributes to the field of forensic crime scene documentation by proposing CS360, a mobile-based system that integrates smartphone technologies with photogrammetric reconstruction and immersive

GRAND ACADEMIC PORTAL
RESEARCH JOURNALS

GAP INDIAN JOURNAL
OF FORENSICS AND BEHAVIOURAL SCIENCES
(ISSN – 2582-8177)
Globally peer-reviewed and open access journal.

ज्ञान: अध्ययन: परम्परा

visualization. The primary contribution of this study is the development of a structured and accessible workflow that enables investigators to document crime scenes using commonly available mobile devices while preserving spatial relationships and contextual metadata. Unlike traditional documentation methods that rely on static photography and manual sketches, the CS360 system provides a 360-degree interactive reconstruction of the crime scene, allowing investigators to revisit and analyze spatial details digitally. The integration of GPS geolocation, timestamp information, and device orientation metadata ensures that captured visuals maintain evidential integrity and verifiable contextual information. Another important contribution of this research is the implementation of a guided capture workflow, which assists investigators in systematically capturing overlapping images required for photogrammetric reconstruction. This approach reduces documentation errors and ensures that complete visual coverage of the crime scene is obtained. Furthermore, the study demonstrates how virtual reality visualization can improve forensic analysis and courtroom communication by allowing investigators, lawyers, and judges to explore reconstructed crime scenes immersively. This capability enhances understanding of spatial relationships and evidence positioning within the environment. Overall, this research highlights the potential of mobile technologies to serve as cost-effective alternatives to expensive laser scanning systems, enabling broader adoption of advanced crime scene documentation techniques across investigative agencies.

LIMITATIONS AND FUTURE WORK

Although the CS360 system demonstrates promising capabilities for mobile-based crime scene documentation, several limitations remain that should be addressed in future research. One limitation involves the dependence on environmental conditions, such as lighting and surface texture, which may affect the accuracy of photogrammetric reconstruction. Environments with low lighting or limited visual features may require additional reference markers to support reliable image alignment. As high-end machineries or laser sensors it cannot click in one go and is time consuming to capture full room. Another limitation relates to processing performance, as complex scenes with large numbers of captured images may require longer processing times, particularly when reconstruction is performed on mobile devices. Future work may explore cloud-based reconstruction pipelines or optimized algorithms to improve processing efficiency. Additionally, while GPS metadata provides geographic verification of captured images, further mechanisms such as secure metadata storage and tamper detection techniques could enhance the evidential reliability of digital crime scene documentation. Future development of the CS360 system may also integrate advanced technologies such as artificial intelligence-based evidence detection, automated object recognition and real-time 3D reconstruction. These improvements could assist investigators in identifying important scene elements more efficiently and further enhance the analytical capabilities of the system.

CONCLUSION

Crime scene documentation plays a crucial role in forensic investigation by preserving the physical environment in which criminal events occur. Traditional documentation methods, including photography and manual sketches, often fail to capture the complex spatial relationships present within crime scenes. Although advanced laser scanning technologies provide highly accurate three-dimensional reconstructions, their high cost and technical complexity limit their accessibility for many investigative agencies. This research introduced CS360, a mobile-based crime scene documentation system designed to utilize smartphone sensors, photogrammetry, and 360-degree imaging techniques to reconstruct crime scenes digitally. The system integrates multiple smartphone capabilities including high-resolution cameras, GPS geolocation, motion sensors, and LiDAR depth sensing to capture spatial information and contextual metadata during scene documentation. The proposed system demonstrates that mobile devices can serve as effective tools for crime scene reconstruction when combined with structured capture workflows and photogrammetric processing techniques. The integration of guided capture points ensures systematic image acquisition, while the VR visualization feature allows investigators and legal professionals to explore reconstructed scenes interactively. By providing a low-cost, accessible, and user-friendly alternative to specialized scanning equipment, the CS360 system has the potential to significantly enhance forensic documentation practices. The system also improves courtroom communication by enabling immersive visualization of crime scenes for judges, lawyers, and investigators. As mobile technology continues to advance, systems such as CS360 may play an increasingly important role in modern forensic investigations, contributing to more accurate documentation, improved analytical capabilities, and stronger evidential presentation within the justice system.

REFERENCES

[1] Cho, S., & Woo, T. (2025). Accuracy of three-dimensional Gaussian splatting for virtual crime scene reconstruction. *Frontiers in Computer Science*, 1755361.
[2] Edward, K. L., Razali, A., Ariff, M. F., Jasni, N. S., Darwin, N., & Majid, Z. (2025). Innovative forensic features and blood spatter 3D reconstruction from geospatial-driven datasets. *Engineering, Technology & Applied Science Research*, 10327.

[3] Jacobsen, C., & Villa, C. (2019). The Application of Photogrammetry for Forensic 3D Recording of Crime Scenes, Evidence and People. *Essentials of Autopsy Practice*, 1–18.

[4] Maiese, A., Manetti, A., Ciallella, C., & Fineschi, V. (2022). The introduction of a new diagnostic tool in forensic pathology: LiDAR sensor for 3D autopsy documentation. *Biosensors*, 132.

[5] Naether, S., Buck, U., Räss, B., & Jackowski, C. (2019). Geomatic techniques in forensic science: A review. *Science & Justice*, 1–8.

[6] Naz, J., Aien, N. U., Fatima, T., & Ansari, M. (2025). Crime scene to judgment: A review on identifying gaps in crime scene investigation and implementing solutions. *Forensic Innovation*, 1–18.

[7] Ospina-Bohórquez, A., Ruiz de Oña, E., Yali, R., Patsiouras, E., Margariti, K., & González-Aguilera, D. (2025). Comprehensive forensic tool for crime scene and traffic accident 3D reconstruction. *Algorithms*, 707.

[8] Peace, M. (2025). Metadata in Digital Forensics: Clues and Conundrums. *Digital Forensic Research Publications*, 1–8.

[9] Pitts, R. A., Wei, M., Yu, J., & Rairden, A. (2020). Empirical comparison of DSLRs and smartphone cameras for latent prints photography. *Journal of Forensic Sciences*, 1391.

[10] Ramos López, R., Sandoval Orozco, A. L., & García Villalba, L. J. (2024). Compression Effects and Scene Details on the Source Camera Identification of Digital Videos. *arXiv Computer Vision Research*, 1–15.

[11] Raoof, A., Yadav, A., Raj, K. K., & Gupta, S. K. (2022). A guide to forensic photography: An indispensable tool in modern forensic medicine practice and medicolegal cases. *Journal of Forensic and Clinical Toxicology*, 1–12.

[12] Ray, N. K. (2024). The Role of Forensic Photography in Criminal Investigation and Trial. *Journal of Social Science and Humanities*, 187–188.

[13] Razali, A., Edward, K. L., Ariff, M. F., Jasni, N. S., Darwin, N., & Majid, Z. (2025). Innovative forensic features and blood spatter 3D reconstruction from geospatial-driven datasets. *Engineering, Technology & Applied Science Research*, 10327.

[14] Singh, H. N. (2021). Crime Scene Investigation. *International Journal of Science and Research*, 543.

[15] Soni, N. (2025). Forensic Value of Exif Data: An Analytical Evaluation of Metadata Integrity across Image Transfer Methods. *Perspectives in Legal and Forensic Sciences*, 1–12.

[16] Yalçın, N., & Gençay, P. S. (2024). Three-dimensional reconstruction of a shooting crime scene. *Global Journal of Academic Research and Review*, 1717.

[17] Zappalà, A., Guarnera, L., Rinaldi, V., Livatino, S., & Battiato, S. (2024). Enhancing Crime Scene Investigations through Virtual Reality and Deep Learning Techniques. *arXiv / IEEE Research Proceedings*, 1–10.