iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.79087

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

Applications of Remote Sensing for Forensic Investigations Using Artificial Intelligence: A Comprehensive Review

Dr. Kapil Kumar[1], Arun Kumar Shukla[2]
[1]Coordinator, Department of Biochemistry and Forensic Science, Gujarat University, Ahmedabad, Gujarat, India
[2]Research Scholar, Department of Biochemistry and Forensic Science, Gujarat University, Ahmedabad, Gujarat, India

Abstract: Modern forensic techniques face increasingly complex forensic scenes and multidisciplinary investigations. Ever-growing volumes of evidence are changing the forensic investigative process and the possibilities for practice. A comprehensive examination of existing applications in which AI enhances remote sensing technologies for forensic investigations is invaluable for developing a future roadmap. This review explores the analysis and the possible value of employing advanced technologies to assist geospatial forensics, including UAV remote forensic investigations, hyperspectral and thermal imaging, synthetic aperture radar, geospatial systems, advanced image processing using deep learning, and multi-sensor data integration. The study focuses on the potential value of forensic investigations and advanced technology systems, reviewing recent innovations and case studies. The paper highlights the value of a multidisciplinary, geoforensic approach that advanced geospatial technologies apply to remote forensics in modern forensics. It also identifies current challenges and outlines future directions to advance modern, futuristic forensic investigations.

Keywords: Artificial intelligence; Remote sensing; Geospatial forensics; UAV forensics; multi-sensor data integration

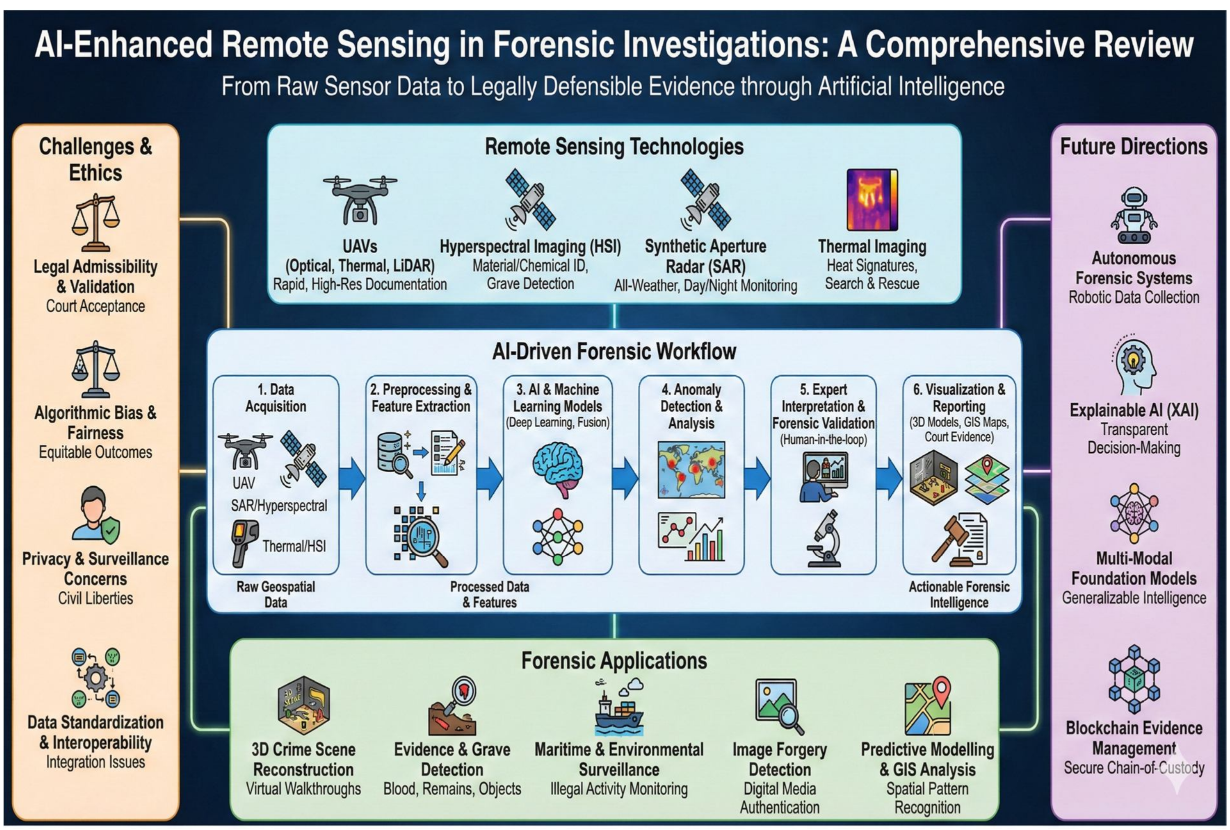


Fig 1 Graphical Abstract

I. INTRODUCTION

A. Background and Significance

Forensic science is a pillar of the criminal justice system because of the various scientific disciplines involved in the preservation and subsequent examination of evidence. However, the traditional techniques of forensic science often encounter problems with accessibility, environmental hazards, financial costs, the degree of manual curation, universal applicability, and the need to extrapolate to the numerous unique situations of a crime and the vast, intricate puzzle of a crime. These problems are even more acute in the forensic examination of mass murder, environmental and cyber crime, and the analysis of transnational crime. Remote sensing is the acquisition of information about an object and a region of interest from a distance. Sensing technologies from primitive aerial orthophotography to advanced multisensor satellite and UAV (drone)-based systems of high spatial, spectral, and temporal data processing. These technologies, applied to forensics processing, the automation of outlier prediction, anomaly detection and prediction, and intelligent analysis, have been heavily improved by the introduction of Artificial Intelligence.[1].

The use of non-invasive evidence collection is a hallmark of forensics, and it is particularly well-suited to remote sensing because it provides the forensic investigator with contactless, digitized evidence, even allowing for protection from danger, rapid analysis, reproducibility, objectivity, preservation, and excellent evidential quality. The benefits of Artificial Intelligence-automated remote sensing profoundly increase the effectiveness and efficiency of forensic inquiry across various fields, especially in areas where conventional forensic methodologies are ineffective, dangerous, or impractical.

B. Objectives and Scope

The primary focus of this review is to present the first AI-integrated remote sensing technology in the critical study of the integration of Remote Sensing and Forensic Investigation. The specific objectives are as follows:

1. To classify, in a remote sensing context, specific types of remote sensing technologies.
2. To explore the forms of AI that support the remote sensing data analysis and empirical forensic investigation.
3. To review, through primary data (field study) or operational case study, the efficiency of the forensic methodologies.
4. To recognize the complexity of technical, legal, ethical, and governance frameworks.
5. To offer a road map to guide future investigation(s) to advance forensic intelligent systems.

The scope includes hyperspectral imaging, synthetic aperture radar (SAR), thermal imaging, UAV-based documentation, GIS-based crime analysis, deep learning-based forensic image analysis algorithms, and multi-sensor fusion, with attention to works demonstrating real-world forensic relevance.

II. REVIEW OF LITERATURE

A. Remote Sensing Technologies

Building on the relevance of AI remote sensing mentioned above, the technological underpinnings and operational mechanics are needed to realize these capabilities in practice. Integrated remote sensing and AI analytical models, implemented in a streamlined manner, enable the execution of a forensic workflow to convert geospatial data into evidence usable in a court of law. This chapter introduces the main remote sensing tools. From crime scene identification to data acquisition and anomaly detection, the complete AI-assisted forensic analysis workflow is described, including human expert analysis and AI-generated evidence reporting. The process flow of AI-based remote sensing for forensic investigation is illustrated through a case study. The diagram provides a simplified explanation of how different technological components, their analytical intelligence, and forensic verification are interrelated.

B. Related Work

Sr. No.	Year	Title	Key Findings	Conclusion	Refences
1	2020	Machine Learning Information Fusion in Earth Observation: A Comprehensive Review of Methods, Applications, and Data Sources	Reviews ML-based fusion of optical, SAR, and LiDAR data	Establishes a foundation for multi-sensor forensic intelligence	[2]

2	2020	ST-CORAbico: A Spatiotemporal Object-Based Bias Correction Method for Storm Prediction Detected by Satellite	GIS + AI improves spatial crime pattern analysis	RS–AI enhances forensic intelligence	[3]
3	2020	Special focus on deep learning in remote sensing image processing Classification: A Survey	DL outperforms traditional RS classification methods	DL is central to modern RS analytics	[4]
4	2021	Reference Measurements in Developing UAV Systems for Detecting Pests, Weeds, and Diseases	Surveys ML techniques for RS classification and detection	ML underpins scalable RS forensics	[5]
5	2021	Research on a Multi-Object Sorting System Based on Deep Learning	HSI + ML enables invisible material detection	HSI is valuable for trace and biological evidence	[6]
6	2021	Area-Wide Prediction of Vertebrate and Invertebrate Hole Density and Depth across a Climate Gradient in Chile Based on UAV and Machine Learning	UAV sensors enhance human detection	UAVs are critical for forensic search operations	[7]
7	2022	State of the Art of User Simulation Approaches for Conversational Information Retrieval.	CNNs improve the detection of small and complex objects	DL enables forensic object identification	[8]
8	2022	Applications of contemporary artificial intelligence technology in forensic odontology as a primary forensic identifier: A scoping review	AI improves efficiency and objectivity in forensics	AI is transformative for forensic workflows	[9]
9	2022	Validating Automatic Concept-Based Explanations for AI-Based Digital Histopathology	Thermal + DL is effective for night-time detection	Thermal imaging supports forensic recovery	[10]
10	2023	3D Indoor Crime Scene Reconstruction Using Micro-UAV Photogrammetry	High-precision UAV-based 3D reconstruction	UAV models are reliable for court presentation	[11]
11	2023	A Scoping Review on Drone Technology Applications in Forensic Science	Reviews UAV use across forensic domains	UAVs support non-invasive investigations	[12]

12	2023	Real-Time Human Detection in Wooded Areas Using UAV Thermal Imagery	DL improves detection under occlusion	UAV thermal sensing aids forensic search	[13]
13	2023	Practical Artificial Intelligence for Remote Sensing	Reviews AI workflows and challenges in RS	Explainability is required for forensic use	[14]
14	2023	Fuzzy Assessment of Ecological Security on the Qinghai–Tibet Plateau Based on Pressure–State–Response Framework	Ecological security on the QTP is generally low, with a median score of 47.4/100, indicating relatively poor overall condition.	There are distinct spatial variations in pressure, state, and response, underscoring the need for region-specific ecological governance and planning.	[15]
15	2024	Identification of Bloodstains Using Hyperspectral Imaging and ML	HSI detects bloodstains with high accuracy	Non-contact forensic detection enhanced	[16]
16	2024	Forensic research of satellite image forgery: a comprehensive survey	DL detects satellite image manipulation.	RS evidence integrity improved	[17]
17	2024	UAV Object Detection Using Deep Learning: A Review	YOLO-based UAV detection is effective	UAVs suitable for forensic monitoring	[18]
18	2024	AI-Based GIS Crime Hotspot Analysis	GIS + AI predicts crime hotspots	Predictive policing strengthened	[19]
19	2024	Multi-Modal Remote Sensing Data Fusion Using AI	Fusion improves detection reliability	Multi-sensor RS is essential for forensics	[20]
20	2025	Search, Detect, Recover: UAV RS for Clandestine Graves	UAVs are effective for grave detection	UAV RS improves large-area searches	[21]
21	2025	Crime Scene Reconstruction: A Scoping Review	Reviews RS-based reconstruction methods	3D RS aids forensic interpretation	[22]
22	2025	Dark Vessel Detection Using Optical and SAR Data Fusion	AI fuses SAR and optical imagery	Maritime forensic surveillance enhanced	[23]
23	2025	Artificial Intelligence Techniques for Digital Forensics	AI accelerates digital evidence analysis	AI is essential for modern forensics	[24]
24	2025	Vision Foundation Models for Remote Sensing	Foundation models improve generalization	Large models aid forensic RS tasks	[25]
25	2025	Remote Sensing Foundation Models: A Survey	Reviews multimodal RS foundation models	Foundation models shape future RS	[25]
26	2025	Predictive Modelling and Drone RS for Burials	Predictive RS improves search planning	AI aids forensic strategy	[26]
27	2025	Autonomous UAV Swarms for Surveillance	Swarm intelligence improves coverage	Future forensic automation	[27]
28	2025	TLSynth: A Novel Blender Add-On for	XAI improves trust and transparency	XAI required for legal forensics	[28]

		Real-Time Point Cloud Generation from 3D Models			
29	2025	AI-Driven Environmental Crime Detection Using RS	Remote sensing–based geo-forensics enables rapid, non-invasive detection of coastal crime scene indicators through multi-sensor, multi-temporal spatial analysis.	Integrating remote sensing with GIS and AI provides a robust, scalable framework for accurate and legally defensible coastal crime scene investigation.	[29]
30	2025	AI-driven crime prediction: a systematic literature review	AI-driven crime prediction models using machine learning, deep learning, and spatio-temporal analytics significantly improve crime pattern forecasting and hotspot identification from large-scale data.	AI-based crime prediction provides strong decision support for proactive policing, but its effectiveness depends on data quality, transparency, and ethical governance.	[30]
31	2025	Blockchain-Based Chain of Custody Evidence Management System for Digital Forensic Investigations	The study demonstrates that a Hyperledger Fabric–based blockchain system ensures a tamper-proof, auditable, and access-controlled chain of custody for digital evidence, reducing reliance on human trust.	Blockchain-enabled evidence management provides a secure, scalable, and legally reliable framework for maintaining digital forensic integrity in modern investigations.	[31]
32	2025	AI and Ethics in Forensic Remote Sensing	AI integration in forensic remote sensing enhances evidence detection, pattern recognition, and decision support, but raises ethical concerns related to data privacy, bias, transparency, and admissibility.	Ethical-by-design AI frameworks that incorporate explainability, accountability, and legal compliance are essential for responsible, trustworthy forensic remote sensing applications.	[32]
33	2025	UAV Geophysical Remote Sensing: A Systematic Review	Reviews UAV-based geophysical sensing	Useful for disturbed-soil detection	[33]
34	2025	Thermal Imaging Datasets for UAV Human Detection	Dataset-driven DL improves detection	Data quality is crucial for forensics	[34]
35	2025	Predictive Policing - Leveraging CCTV Data and AI for Crime Hotspots	AI-driven analysis of CCTV data enables accurate identification of crime hotspots through real-time pattern recognition, behavioral analytics, and spatio-temporal clustering.	Predictive policing using CCTV and AI enhances proactive crime prevention, but must be implemented with robust safeguards to protect privacy, mitigate bias, and ensure legal accountability.	[35]

Table 1. Chronological summary of key research (2020–2025) on the integration of artificial intelligence and remote sensing technologies for forensic intelligence, crime scene analysis, evidence detection, and investigative decision support, highlighting core methodologies, key findings, and forensic relevance.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

C. Synthesis of Reviewed Literature

The literature reflects the impact of the interplay between artificial intelligence and remote sensing technologies and the evolution of forensic investigations. In the beginning, literature documented the role of machine learning and deep learning in remote sensing data classification, object detection, and spatial analysis. In subsequent studies, the integration of optical, SAR, thermal, hyperspectral, and LiDAR data streams in multi-sensor data fusion and its value for detection and uncertainty assessment in complex forensic studies were documented. The more recent studies emphasised the operational use of the technologies in deploying UAVs for intensive three-dimensional reconstruction of crime scenes and the detection of humans in varied programmed automated environments. The literature documents the shift in the concepts of technology toward ethically explainable and legally robust Artificial Intelligence, as well as other concepts such as foundation models, swarm-autonomous UAVs, blockchain for evidence management, and the detection of Environmental crime. Challenges in multidisciplinary forensic science, including built-in accountability and other complexities, must be investigated for the use of remote sensing technology integrated with Artificial Intelligence.

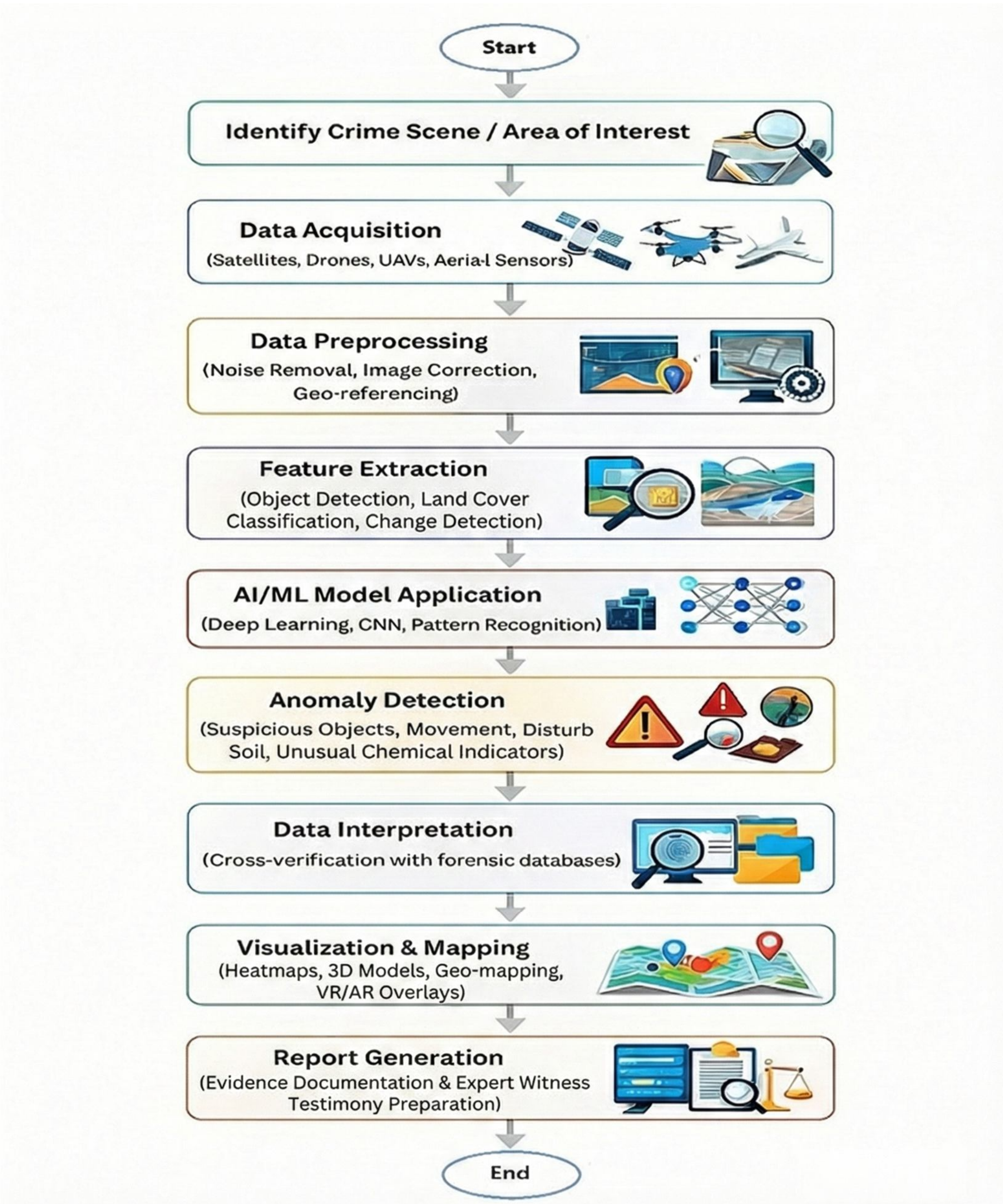


Fig. 2 illustrates the complete AI-driven remote sensing workflow for forensic analysis, highlighting the interaction between data acquisition, AI analytics, expert validation, and legal evidence presentation.

D. Process Flow

Assisted by artificial intelligence, remote sensing has become more streamlined, systematic, and non-invasive, especially in complex forensic scenarios and in inaccessible regions. The forensic workflow, in its entirety, begins with the geospatial data acquisition and harvesting from varying levels, from satellites, UAVs, and airborne sensors down to ground-based sensing systems. The data, required from multiple systems, include optical images, thermal photographs, hyperspectral data cubes, radar signals, and LiDAR point clouds. After collection, the data undergoes various preprocessing steps, including noise reduction, radiometric and geometric corrections, normalisation, and georeferencing. This ensures data quality and synergy, enabling interoperability. The preprocessed data are then passed to analytical AI models, algorithms of machine learning and deep learning, to detect forensic patterns that are of interest, such as anomalies in disturbed soils owing to an emplaced body, tracks from vehicles, irregular thermal patterns, and spatial vegetation anomalies, and other detectable clues of criminal activity. AI models do not provide outputs that can be considered as conclusions. Specialists in forensics and geospatial analysis evaluate each output. This human-in-the-loop system enables identification of the most likely field investigation locations and is the first step in truth verification. This is the process by which the AI system's predicted locations of the sites of interest are evaluated through physical examination, excavation, and other forensic techniques. The information obtained through physical investigation is used to improve the AI system further, thereby refining the prediction process and reducing the rate of erroneous outputs. Ultimately, the other forensic evidence, including biological evidence, digital data, testimony, and documentation of the crime scene, is merged with the confirmed geo-spatial evidence. These combined outputs, geospatial data in conjunction with other forensic information, are enhanced for visualization, 3D reconstruction, and summary reporting to support analytical reasoning and presentation in court [36].

E. AI-Centric Remote Sensing Forensics Process: Workflow

This section of the research presents a fully inclusive forensic system for remote sensing and artificial intelligence. The series of geospatial data, the final stage of the data processing, is fully integrated with a series of systems that ensure the data is processed into scientifically sound and legally valid forensic evidence.

1) Commencing With a Forensic Investigation: A flow chart representing a process begins with the start of a forensic investigation, and this is most often the result of a crime, a missing person(s) case, an environmental crime, a disaster, or a report from a concerned citizen. At this stage, the investigation's goal is determined, which dictates the analytics and technology for every subsequent stage.
2) Identifying a Crime Scene or Area of Interest: The first operational stage is the identification and the geo-spatial outlining of the crime scene and/or area of interest (AOI) (of investigation). This involves setting the geo-spatial boundaries of interest for the investigation using some basic data, including, but not limited to, testimonies from witnesses, historic crime patterns, satellite imaging (in reconnaissance form), or police data. In several forensic scenarios, including but not limited to, clandestine grave searches, unpermitted mining, fraudulent border-evading shipping (maritime smuggling), and large environmental crimes, the AOI can be very large, or located in remote, or very inaccessible; logistical planning should be strictly adhered to (as an operational boundary), due to the impact sudden deviations can have in several areas, including planning appropriate technology and the level of detail required in data analyses, etc.

F. Data Acquisition

After defining the area of interest (AOI), additional geospatial data is collected using various remote-sensing systems, such as satellites, drones, and manned aircraft. Other systems can be ground-based. Data collection can include captured optical images and other geospatial data, such as hyperspectral, thermal infrared, synthetic aperture radar (SAR), and LiDAR. Using multiple remote-sensing platforms is effective for achieving the desired spatial, spectral, and temporal data coverage while also preserving non-invasive, safe approaches to the forensic crime scene.

G. Data Preprocessing

Sourcing the collected data is followed by data preprocessing to ensure the data can be analyzed reliably. Editing and refining the data involves several steps: removing noise, applying corrections (radiometric, atmospheric, and geometric), enhancing the images, aligning them to designated georeferenced coordinate systems, and standardizing the datasets to ensure compatibility. The goal of these steps is to mitigate the impacts of sensor differences, environmental factors, synchronization, and source differences in the collection of datasets, thereby preparing the data for accurate feature extraction and analysis using artificial intelligence (AI).

H. Feature Extraction

After the necessary preprocessing steps are completed, feature extraction becomes the next priority for identifying meaningful attributes in the georeferenced data. This activity includes object detection, land cover classification, texture analysis, and change detection over time or space. Possible attributes of interest in the data may include disrupted soil patterns, vehicle trackways, anomalous vegetation stress, changes to the built environment, or other signature attributes within the geographical scope of an investigation. Feature extraction transforms unorganized, pixel-level data into a form that is amenable to more sophisticated processing and meaningful analysis.

I. Ai And Machine Learning Model Application

The next step is to process the data featuring the geographical attributes of interest using AI and machine learning (ML) models, including deep learning architectures such as convolutional neural networks (CNNs). These models are engineered to recognize complex spatial and spectral patterns that may be beyond human analysis. AI processing is characterized by the ability to perform rapid analysis of very large data volumes and, when combined with ML algorithms, offers greater detection sensitivity and reduced human involvement. This processing is particularly amenable to large or complex forensic investigations.

J. Analysis Of Operational Records

One of the final stages of the workflow involves detecting anomalies, where the trained AI models recognize nonstandard environmental and/or spatial patterns.

These may be the presence of objects of interest, specific movements, changes in the soil, abnormal temperatures, changes in the color and/or composition of the soil, or changes in chemical signatures. Abnormal pattern detection assistance in identifying areas with a high probability of interest, thus significantly reducing the search area and enhancing the efficiency of targeted field examinations, improving the use of available resources.

The results generated by AI are subject to expert interpretation and forensic validation. This step uses the human-in-the-loop model and involves cross-matching AI observations with forensic databases, historical records, and contextual information. Mistakes such as ground truthing, where physical observations, excavation, or other forensic methods are used to confirm the AI's predictions, are common. Validation is necessary to gain scientific credibility, reduce false positives, and ensure that forensic evidence is legally adequate.

K. Visualization And Mapping

Different formats are used to help users comprehend and communicate the data analysis results. Thus, the results are presented as geospatial maps, heatmaps, 3D models, and GIS overlays that show the spatial relationships among evidence items. Even sophisticated techniques such as virtual and augmented reality (VR and AR) are used to provide immersive visualization of crime scenes. Visualization serves as an essential bridge between technical analysis and investigation or judicial interpretation.

L. Evidence And Report Writing And Courtroom Preparation

The final phase of the analysis is the synthesis of evidence and report writing, in which all processed findings are organized coherently. Reports discuss the procedures, methods, analyses, results, associated visualizations, uncertainties, and opinions. Such reports are tailored to the interface between forensic science and the law to facilitate expert witness testimony and judicial examination. Merging AI-generated results with traditional forensic evidence complies with standards to ensure the process is transparent and reproducible, thereby enhancing the likelihood that the findings will be accepted in court.

M. Conclusion Of The Forensic Analysis Cycle

There is a forensic analysis workflow in which the results can be used for further investigative work or in court proceedings. However, the cycle is expected to be iterative, as the results can improve the techniques used in data collection, AI models, and forensic analysis, depending on feedback from field validation, peer review, or the courtroom.

The data workflow shown in the figure represents the first fully-integrated and highly automated forensic intelligence system. This system enables objective, replicable forensic analyses at scale. The combination of remote forensic investigation, the automation of artificial intelligence remote validation, and the insertion of legal text represents an advancement in forensic investigation beyond borderline forensic capabilities.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

N. Differing Methods And Applications Of Remote Sensing Technologies

Remote sensing methodologies offer an unprecedented suite of tools, thereby significantly expanding the scope of forensic investigations, particularly in scenarios where conventional ground-based methods are infeasible or restricted by time, safety, accessibility, or the scale of the investigation. Remote sensing technologies enable non-intrusive examination and, at the same time, efficient and effective surveillance of large areas to detect and monitor subtle environmental changes, or at the immediate crime scene, which might otherwise go undetected.

All remote sensing technologies are distinguished by the unique physical principles governing their operation, as well as the advantages and disadvantages of each in the context of forensic investigations. Important design constraints relevant to any remote sensing technology stave off investigations of certain forensic questions are: the trade-off between spatial detail and spectral sensitivity, weather-dependent operational constraints, and high cost and complexity at the analytics stage of the project. For instance, affordable, highly detailed UAV-optical imaging from crime scene photography is an effective but limited tool in forensic investigations. Affordable, highly detailed, reliable, continuous tracking of sites and monitoring of scattered objects are underrepresented in the literature and enabled by advanced SAR in low-visibility weather conditions. Forensic applications of major remote sensing technologies, their operations, primary forensic applications, weather dependencies, and costs are detailed in Table 1. This comparison allows forensic professionals to select suitable technologies for their investigations, taking into account the objectives, the technologies' weather dependencies, and costs [37].

Remote Sensing Method	Operating Principle	Primary Forensic Applications	Weather Dependency	Cost Level
UAV with Optical Camera	High-resolution RGB imagery acquired from aerial platforms	Crime scene documentation, 3D reconstruction, and evidence mapping	High (requires clear weather)	Low to Moderate
Hyperspectral Imaging (HSI)	Acquisition of hundreds of narrow spectral bands across the electromagnetic spectrum	Buried remains detection, material discrimination, trace evidence analysis	Moderate (affected by atmospheric conditions)	High
Synthetic Aperture Radar (SAR)	Emission and reception of microwave signals reflected from the surface	Maritime surveillance, illegal activity detection, border monitoring	Low (operates day and night, all-weather)	Very High
Thermal Imaging	Detection of infrared radiation based on surface temperature variations	Body detection, concealed evidence identification, and search operations	Moderate (optimal in cooler ambient conditions)	Moderate to High
LiDAR	Laser pulse emission to generate high-density 3D point clouds	High-precision 3D mapping, terrain, and structure analysis	Moderate (performance may degrade in rain or fog)	High
GIS-Based Analysis	Integration and spatial analysis of georeferenced datasets	Crime mapping, spatial pattern analysis, resource allocation	None (data-driven, weather-independent)	Low
Deep Learning Image Analysis	Neural network–based visual pattern recognition and classification	Forgery detection, object recognition, and evidence classification	Sensor-dependent	Low to Moderate
Multispectral Imaging	Imaging using a limited number of discrete spectral bands	Vegetation stress analysis, environmental and ecological forensics	Moderate (similar to optical imaging)	Moderate

Table 2. Summary of major remote sensing modalities employed in forensic investigations, outlining their operational principles, application domains, environmental constraints, and cost considerations.

III. UNMANNED AERIAL VEHICLES (UAVS) FOR NULLA INFINITUM DOCUMENTING

A. Aerial Technology in Forensic Science

The use of unmanned aircraft systems (UASs) in forensic investigations has dramatically changed the field because of their ability to capture non-invasive photographs of crime scenes from multiple heights and angles in real time and at high resolution. Current UAV models include a range of sensing tools, such as optical camera systems, Light Detection and Ranging (LiDAR) sensors, thermal and infrared cameras, and GPS, enabling the capture of evidence and spatial mapping of crime scenes. UAVs excel here because the scenes are often contaminated, hazardous, or remote, where ground-based documentation cannot be safely conducted due to the risk to the investigator.

The incorporation of artificial intelligence (AI), such as intelligent embedded systems, real-time processing, and decision-making algorithms, enhances UAV systems from passive forensic tools to active forensic platforms. AI complements any or all UAV capabilities, including flight planning, evidence detection, evidence capture, geotagging, evidence frame annotation, and scene-adaptive imaging. These features lead to greater efficiency and objectivity in forensic documentation.

B. The Role of AI in 3D Crime Scene Reconstruction.

AI-enabled UAVs are essential for 3D reconstruction of crime scenes, as they capture overlapping aerial images, enabling photogrammetry to generate accurate, georeferenced 3D models and orthomosaics. The convolutional neural network reconstruction improves feature extraction, geometric distortion correction, segmentation, and classification of forensic evidence.

The reconstructions allow a user to virtually revise the scene in question, remeasure areas of interest, analyze blood patterns and trajectories, and reconstruct the scene, thereby avoiding repeated physical examination of the crime scene. The 3D crime scene reconstruction models have also been very useful and practical during the trial phase of a case, clarifying and helping the court understand the concepts and interrelationships among the various points and areas in a 3D crime scene. Numerous studies also attest to the accuracy of UAV reconstructions, especially in closed indoor environments, with high spatial precision.

C. The Role of AI in Real-Time Evidence Detection.

With the advancement of AI, the field of forensic science has also gained a lot of attention. UAVs can now autonomously detect and classify evidence in real time during flight. For example, deep learning models applied to forensic evidence datasets can differentiate and classify blood, weapons, footprints, human remains, and disturbed soil. UAV systems detect forensic evidence in real-time and improve operational efficiency.

In forensic applications, AI-empowered drones capture complex and remote crime scenes by taking images from multiple angles, automatically marking forensic sites of interest, and creating 3D models. These deliverables enable fraud analysts and investigators to perform more sophisticated event borrowing automation by building detailed timelines and trajectory streamlining, thus lightening their workload and increasing the number of cases fraud analysts and investigators can handle while increasing the level of accuracy.

D. Operational Advantages and Limitations

Forensic analysis done via drones has many conveniences, such as the ability to be deployed instantly. They also cover larger areas while contaminating the crime scene only minimally or not at all. The operational simplicity of drones and their lower costs relative to human-crewed vehicles further enhance their advantages. These benefits make drones the optimal choice for large-scale operations, disaster victim identification, and forensic searches in isolated and dangerous regions.

Disadvantages also exist, however. The operational capacity of drones is very much dependent on prevailing weather conditions, such as strong winds and rain. These pose risks to overall operational stability or image clarity. Battery life also restricts the time drones can be airborne. There are also legal and ethical considerations that must be respected, especially in urban areas. There may also be unregulated privacy concerns, and the drones may have to be operated by specialists trained in forensics[38].

IV. HYPERSPECTRAL IMAGING FOR FORENSIC APPLICATIONS

A. Principles of Hyperspectral Imaging

Hyperspectral imaging produces several hundred closely spaced spectral bands to derive both spatial and spectral information for every pixel of interest, building a high-dimensional data cube. In contrast to RGB imaging, which is confined to three color bands, hyperspectral imaging can detect subtle, more detailed material signatures and detect certain chemicals and biological activities that are not visible.

Hyperspectral imaging, combined with AI, specifically, machine learning and deep learning, can assist in automated processes of material discrimination, outlier detection in multivariate datasets, anomalous scene detection, changes in datasets over time, and in the construction of predictive models in forensic science. In certain forensic case work, applications of these capabilities exhibit remarkable classification performance.

B. Detection of Clandestine Graves

Hyperspectral imaging with AI in precision agriculture applications has demonstrated the ability to detect clandestine graves by detecting subtle spectral changes in soil composition and vegetation that indicate the presence of human remains. Such changes are not perceptible with classical imaging methodologies, and are only detectable with advanced spectral analysis paired with high-order attribute pattern recognition systems.

During the post-burial period, moisture stress and spectral responses are most apparent, affecting the accuracy of detection for machine and deep learning models. Airborne hyperspectral technology enables rapid aerial imaging of expansive areas that would be inefficient to investigate on the ground. This makes hyperspectral imaging particularly useful for detecting unmarked graves across large areas with varying terrain.

C. Post-Mortem Interval Estimation

For estimating Post-Mortem Interval (PMI), especially with skeletal remains, portable hyperspectral imaging devices paired with artificial intelligence have proven effective. Recent advances in the differentiation accuracy of forensic and archaeological remains have been achieved with deep learning models developed to analyze hyperspectral datasets.

These non-contact devices can capture visible and near-infrared spectral data instantaneously, enabling the development of a rapid, objective, and non-destructive methodology for estimating PMI. Their ease of use and ability to work swiftly make them an appropriate choice for analysis in the lab and in situ.

D. Forensic Scene Analysis and Evidence Detection

Hyperspectral imaging (HI) fused with artificial intelligence (AI) enables the detection and differentiation of forensic evidence not visible to the naked eye, including bloodstains and other bodily fluids, gunshot residue, trace fibers, soil particles, forged documents, and latent fingerprints. Spectral signature analyses performed using deep learning models enable the classification of materials, the differentiation of visually similar substances, and the accurate estimation of concentration. Hyperspectral imaging is also utilized in forensic odontology, analysis of wound patterns, and document verification. Ongoing miniaturization of hyperspectral sensors and advancements in artificial intelligence are facilitating the use of this technology in everyday forensic work.[39].

V. SYNTHETIC APERTURE RADAR (SAR) FOR SURVEILLANCE AND MONITORING

A. SAR Technology and Forensic Utility

Synthetic aperture radar (SAR) is an active remote sensing technology in which microwave signals are transmitted and reflected from the target surface to produce a detailed image of the terrain. SAR is not like an optical sensor, as it can image and record at any time of day, under any weather conditions (i.e., it can penetrate clouds). SAR can be used to capture and record relayed imagery under any conditions and at any time.

Spatial resolution can be improved through synthetic aperture processing (integration of several radar captures) as the sensor moves. When combined with artificial intelligence, SAR technology can automate the detection of changes, anomalies, and objects in data, as well as perform behavioral analyses and integrate with other sensors. As a result, SAR empowers forensic teams to identify complicated surface changes and activities that would otherwise be impossible to discern.

B. Monitoring Maritime Activities

SAR technology is always a prominent element of maritime forensic surveillance, especially for monitoring illegal activities such as unreported fishing, drug smuggling, sanctions evasion, customs evasion, deceptive shipping, and illegal border crossings. Implanting artificial intelligence in SAR facilitates tracking of how certain vessels disable and/or spoof transponders to elude detection by other vessels and monitoring systems. Behavioral irregularities, such as excessive hovering in no-fly zones or transfers between ships, can be identified by consistently observing each vessel's movement patterns. A combination of SAR and other optical/infrared/electronic sensors is necessary for higher-level maritime intelligence and overarching situational awareness.

C. Monitoring of Environmental Crimes

The monitoring of environmental crimes such as illegal logging, illegal mining, oil spillages, and the abandonment of toxic waste are other instances where Enhanced SAR has been employed. SAR's ability to see through the atmosphere and darkness makes it exceptionally well-suited to monitor the vast remote areas where such activities are most prevalent.

In the analysis of SAR data, various aspects, such as change detection, signature recognition, and monitoring the advancing impacts of the environment, are mechanisms through which machine learning is deployed. Monitoring of ground deformation is also important, particularly in illegal mining and construction, and it is done using SAR interferometry. Subsidence monitoring is especially well done with it.

D. Infrastructure and Border Surveillance

SAR satellites enable continuous monitoring of specific infrastructure, borders, and sensitive areas, facilitating forensic recording of illegal invasions, infrastructure damage, disaster impacts, and breaches of international treaties. The latest SAR satellites offer high spatial resolution, enabling forensic identification of specific vehicle classes, particular structural patterns, and activity patterns [40].

VI. THERMAL IMAGING FOR FORENSIC DETECTION

A. Thermal Imaging Principles and Forensic Applications

The fundamentals of forensic thermal imaging systems are based on the recording of IR radiation emitted by the object of interest, which depends on its temperature. Sensitive detectors translate the received IR radiation into thermal images. Thermal imaging systems are not restricted to visible light. Hence, even in very dark conditions with no external illumination, a thermal imaging system can capture images of objects and their thermal patterns. In forensic investigations, the advantages of thermal imaging systems are that there is an ability to see through smoke, fog, and light rain; the system can detect the heat associated with a recently disturbed surface; the imaging system can reveal concealed objects that have thermal contrast with their environment, or substances that are hidden by the underlying surface. These advantages make thermal imaging systems very useful for night operations, situational assessments following an incident, or searches in very complex or dangerous environments. The improvement of artificial intelligence further develops the thermal imaging technology used in forensic science. With the help of AI, it is possible to automate the detection and classification of anomalies in thermal images, the analysis of thermal images over time, the overlaying of thermal images with other imaging data, and the analysis of thermal images in the visible light spectrum to improve data quality. Deep learning algorithms trained on forensic thermal imaging datasets can increase the reliability of forensic imaging by detecting and distinguishing specific forensic thermal signatures, thereby reducing the incidence of false-positive results.

B. Body Detection and Search Operations

The use of thermal imaging in forensic science has also greatly improved the effectiveness of search-and-rescue operations. These operations include searches for missing and deceased persons, as well as for possible evidence. Thermal imaging is used in a variety of difficult-to-navigate terrains. The thermal imaging camera can identify people and dead individuals in the early active stages of decomposition. The camera can also identify ectothermic organisms, as their heat signatures will contrast with the background. By utilizing advanced thermal imaging and correct imaging settings, organisms can be identified.

Longitudinal studies show that surface human remains are detectable throughout the active stages of decomposition. However, other factors affect the body's thermal decomposition, including the stage of decomposition, ambient temperature, and time of day. In the early post-mortem period, thermal imaging is more useful when performed in the morning. In later decomposition stages, images taken in the afternoon or evening are more likely to yield, as environmental temperatures are more volatile.

AI-assisted thermal imaging systems improve operational efficiency by automatically detecting heat signatures associated with decaying bodies, differentiating between human and animal thermal emissions, and prioritizing target heat clusters for further analysis. Integrated with thermal sensors and drones, these systems can rapidly and efficiently scan large areas. They are thus well-suited to search operations in remote locations, disaster recovery, and other inaccessible areas.

C. Application of Thermal Imaging to Evidence Recovery at a Crime Scene

AI thermal imaging also has other applications in forensic science, particularly in analyzing crime scenes and in real-time monitoring during a forensic investigation. These systems also provide real-time event monitoring with thermal cameras that automatically detect and track suspicious thermal activity, including abnormal heat emanating from concealed weapons, recently manipulated items, clusters of people whose behavior suggests irregularity or concealment, or other potential hostile thermal signatures. These systems also provide event monitoring by triggering an alert to the user, directing them to a region of interest for further investigation. The use of thermal imaging offers benefits, but it also has limitations to consider. While thermal imaging may be effective in extreme conditions, such as blazing heat and heavy rain, it is less effective in other conditions, as it cannot see through materials that thermal sensors cannot. In addition, reduced thermal sources may not be cross-referenced forensically. Thus, for forensic thermal imaging, a forensic expert and a high level of AI training are necessary to conduct a comprehensive analysis and minimize systemic false positives.

The surveillance and privacy of this technology are, and will be, the focus to ensure appropriate controls, legal frameworks, and ethical use. Advanced thermal imaging may come with the privacy of forensic investigations. Balance the technology and the privacy of individuals under forensic investigations to advance thermal imaging, as well as forensic investigations.[41].

VII. GEOSPATIAL INFORMATION SYSTEMS (GIS) AND CRIME ANALYSIS

A. GIS Fundamentals in Forensic Science

By integrating, visualizing, and analyzing spatially referenced data, geospatial information systems (GIS) play a distinct and vital role in the analysis of spatial data in academia and forensic science.GIS programs can incorporate several types of information, such as the locations of crime incidents and/or demographic data, the locations of infrastructure networks, terrain characteristics, satellite and aerial images, time-indexed data, and others, and then support comprehensive spatial analysis. This capability of GIS programs enables spatial and geographic analysis of relationships and dependencies that may not be easily revealed by traditional forensic analysis. The integration of artificial intelligence (AI) significantly enhances GIS's forensic analysis capabilities. AI-enhanced GIS applications make it easier to model crime prediction, spatial pattern recognition, resource allocation, and advanced spatial reasoning. Crime hotspot forecasting, geographic profiling of criminals, analysis of movement and travel routes, and assessment of the relationship between crime and various environmental factors, and GIS applications incorporate several machine learning (ML) algorithms to enable prediction. GIS serves as a descriptive map and a predictive and prescriptive decision-support system for forensic science and law enforcement.

B. Crime Mapping and Spatial Pattern Analysis

The automated detection of crime hotspots using spatio-temporal trend analysis and clustering is just one way AI-enhanced GIS enables advanced crime mapping and spatial pattern analysis. Spatial crime analysis allows investigators to visualize the relative locations of criminal events and recognize patterns in space and time. Geography of crime also allows for the study of the relationships between different types of crime and their geographical determinants, including transport systems, commerce, and residential areas.

By analyzing previous crime data and spatio-temporal patterns, machine learning can identify patterns and allocate resources for investigation and patrol at specific time intervals and locations. The crime pattern feedback loop improves real-time awareness and strategic efficiency for police forces. Systems focusing on analytical crime data can reduce crime rates to statistically significant levels. Consequently, crime mapping has emerged as a core component of international crime analysis today.

C. GIS Support for Forensic Investigations

There are several subjective and objective activities in forensic investigations that benefit from GIS's analytical capabilities. Georeferencing, automated 3D spatial visualization, and spatially-integrated chain of custody are just a few of the principal functions. GIS can also enhance spatio-temporal reconstruction of a suspect's activities and movements by integrating GPS, video, and witness accounts. Moreover, witnesses' testimonies can be spatialized and geographically analyzed, and GIS can be employed to assess and verify spatial testimonies. GIS and remote sensing simultaneously provide investigators with the means to assess altered terrain and conduct line-of-sight and visibility analyses using contemporary satellite and aerial photographs of the site. These tools illustrate and clarify the relationships in the evidence and provide spatial and forensic evidence to help investigators, the courts, and the investigators set and present informed, reasoned spatial evidence.

D. Predictive Policing and Resource Allocation

While the topic is controversial, predictive policing is one of the most well-developed diagnostic tools in crime analysis. It attempts to analyze heterogeneous, complex, vast, and large contemporary and historical crime records and datasets, as well as geographical and demographic records and datasets, and time and weather conditions. It used automated machine learning to discover and model intricate relationships in datasets, providing evidence-based predictions to help law enforcement with operational tasks and to inform evidence-based decisions. Even though predictive policing systems optimize patrol assignments and reduce low-level crime, ethical and social dilemmas remain. Predictive policing systems do not address the embedded algorithmic bias in historical data; extensive data collection can violate individuals' privacy rights; and predictive feedback loops can exacerbate the overpolicing of specific populations. Implementing predictive policing systems requires transparency in the algorithms used, regular audits to identify bias, mechanisms to ensure accountability, and community engagement to safeguard the social values of equity and justice [42].

VIII. DEEP LEARNING FOR IMAGE FORENSICS AND ANALYSIS

A. Deep Learning Architectures for Forensic Applications

Within forensic image analysis, deep learning – a particular subfield of machine learning characterized by the engagement of multi-layered, artificial neural networks – has revolutionized the capacity for automation in the sub-discipline by enabling feature extraction, recognition of complex patterns, classification of data, and the identification of anomalies – all at a scale unfathomable to a human operator. In contrast to traditional approaches to analysis, such as rule-based and handcrafted feature systems, deep learning models are trained unsupervised from data, enabling them to learn complex relationships. Convolutional Neural Networks are preferred over other forms of artificial intelligence in forensic image analysis applications because they tend to demonstrate superior performance in tasks that require the retrieval of information in proximity to each other in the neural network architecture and where the position of the information is not static (i.e., spatial locality and translation invariance). The forensic image analysis applications that are based on convolutional neural networks of real time object detection for retrieval of forensic images with the aid of convolutional neural networks, deep neural networks for image feature retrieval and categorization, autoencoders for the detection of anomalies and reconstruction of images that are incomplete or degraded, and generative networks for the detection of forgeries and the synthesis of images for use in the training and validation of forensic applications. These applications can be trained on large-scale forensic images to constrain training further or to refine image retrieval based on evidence types and varieties.

B. Image Forgery and Manipulation Detection

Digital image forensics primarily focuses on detecting alterations and forgeries in photographs. These image forensics studies cannot be considered complete due to advances in image editing applications and the generation of synthetic images. Employing advanced deep learning techniques is the only method that enables fully automated recognition of image alterations and supports real-time detection. The alterations that can be detected in real time include splicing, copy-move, retouching, inpainting, deepfake generation, and metadata alterations. These models identify minute genre-specific statistical irregularities, texture inconsistencies, compression artifacts, and lighting changes at the pixel and feature level that often evade the human eye. In remote sensing and satellite imagery, the determination of forgery is paramount to supporting evidence that the courts permit in environmental crime, land-use fraud, and claims of damage to the infrastructure, as well as intelligence assessments, and Deep learning models identify minute manipulations and outperform traditional methods and handcrafted feature-based methods, especially with appropriate training on rich and representative datasets

C. Biometric Identification and Recognition

Deep learning has revolutionized biometric identification and recognition in forensic science by enabling fast, reliable, and limitless analysis of human biometric data. AI applications in forensic biometric systems include fingerprint recognition, facial recognition in surveillance footage, iris recognition in high-security settings, voice and speaker recognition, and suspect tracking through gait analysis. Within a few minutes, deep neural networks capture unique biometric characteristics and compare them against large-scale databases, enabling them to identify a single entity among millions. This approach minimizes the impact of the human factor, supports processing large forensic queues, and enhances the flexibility of multimodal biometric systems that simultaneously analyze multiple biometric traits. Continuous model training allows systems to improve over time. Of major concern, however, deep learning-based biometric systems have been associated with algorithmic bias, false-positive errors, and inadequate safeguards for personal privacy. These issues underscore the importance of thoroughly testing systems and the need for appropriate transparency and ethical use.

D. Digital forensics and cybercrime investigation

In the field of digital forensics, the use of deep learning to address the enormous, constantly increasing volume of digital evidence related to cybercrime is invaluable. These include the detection and classification of malware, the detection of network intrusions, the analysis of encrypted or obfuscated data, the identification of unauthorized digital content, and the detection of coordinated illicit online activities. 9. Multi-Sensor Integration and Data Fusion[43].

IX. REMOTE SENSING SYSTEMS

A. Integrated Remote Sensing Platforms

Contemporary forensic investigations are beginning to incorporate multi-sensor remote sensing technologies to overcome the challenges associated with single-sensor technologies. Such platforms consist of optical images that are used to identify and understand the context, synthetic aperture radar (SAR) that is used for all Weather, day and night surveillance, thermal imaging used to detect heat, and LiDAR used for high accuracy, three-dimensional measurements, and hyperspectral imaging, which is used to detect highly detailed elements and differentiate various materials and chemicals. Artificial intelligence is at the center of these processes and is responsible for the challenges posed by consolidating these various forms of information. Data Fusion algorithms take information from each technology and each imaging sensor and fill gaps with data from these sources. Potential evidence is detected by corroborating data from multiple sensors. The use of multi-sensor data conjunction provides a means to enhance monitoring, present different data obtained for the same forensic investigation to reduce the chances of false data presentation, reduce the risk of incomplete data, and enhance understanding of the information presented by different sensors.

In addition to examining location attributes, forensic analysis of spatial parameters can be applied to correlate analytical designs with geovisual representations, cost descriptors, sounds, and sensor metadata. This approach facilitates the effortless discovery of interrelationships during cross-examinations, thereby testifying to the cross-examination's circularity, and assists in the advanced reconstruction of exemplary narratives. Regarding radar surveillance and tracking, the fusion of signal detection, optical surveillance, and signal intelligence directly augments situational awareness and improves forensic analytics performance.

B. Autonomous Forensic Systems

For the future of fully autonomous forensic systems, integrating AI with multi-sensor forensics is very promising. Fully autonomous systems will likely include multiforensics, artificial intelligence systems, and sensors on robotic and drone systems capable of performing forensic analyses with minimal human interaction. It is reasonable to assume that advanced forensic systems will be capable of autonomously performing initial forensic evidence collection, real-time analysis of the evidence, and electronically distributing the verified evidence to forensic information systems. It is also reasonable to assume that autonomous systems could be used to document and reconstruct the crime, evidence chain of custody, and provide analytics on the instructions. AI-enhanced systems should also enable digital twins of the crime scene for interactive walkthroughs, allowing investigators to form and test hypotheses, analyze, and pose scenario queries on trajectories and spatio-temporal elements without altering the original crime scene. Emerging autonomous forensic systems focus on secure, safe data systems to preserve evidential integrity and admissibility. For example, authentic, tamper-proof evidence, transparent and immutable audit trails, and decentralized Identities can be achieved through the use of blockchain distributed ledgers. The combination of multi-sensor fusion, autonomous intelligence, and secure data systems is a major step toward scalable, unbiased, and next-generation forensic investigation systems.[44].

X. CHALLENGES

A. Data Format Standardization and Interoperability

While the prospects of AI-enabled remote sensing, multi-sensor fusion within a single platform, and forensic investigations are promising, several challenges remain. One of the challenges is the lack of standardized data formats and interoperability among heterogeneous sensing systems. Remote sensing data is obtained from various sensor systems, each with different spatial resolution, spectral range, temporal resolution, and file formats. This creates a situation in which data from different sensors cannot be integrated and analyzed comprehensively. Calibrating sensors, aligning datasets across modalities, and performing real-time processing demand substantial computational power. Forensic reasoning becomes more complicated when uncertainty about each sensor is taken into account. As a result, forensic AI systems must account for sensor failures, poorly structured or low-quality datasets, and the generation of outputs for forensic processing and elucidation for the court.

B. Legality and Validation

Applying AI and remote sensing to forensic investigations raises legal and ethical issues regarding the use of AI in forensic evidence. Legal forensic evidence must meet evidentiary thresholds, and in particular, be methodologically transparent and reliable, replicable, and validated to have a certain level of error over time. Therefore, AI in this case needs to be validated to a certain extent using external datasets, peer-reviewed, and comply with the field's standards. In no less measure, the systems that support algorithmic decision-making must be transparent so that experts can testify and be cross-examined. Forensic AI should undergo instantiable validation processes designed primarily for transparency and control. Without these processes, the evidentiary quality of AI-assisted forensics can be challenged in investigations or in court.

C. Algorithmic Bias and Fairness

One of the dominant ethical and practical challenges of AI use in the forensic sciences is algorithmic bias. Biases in the training data and in the data the model is designed to use affect the model's error rate across different population subgroups, potentially leading to outputs that are unfair and discriminatory. Bias is particularly troubling in forensic settings, where erroneous identifications or risk assessments may lead to adverse legal or social outcomes. Mitigating algorithmic bias will require the use of training data that is sufficiently varied and representative, model audits that assess model outputs for fairness-related variation, transparency in the development and deployment of the model, and positive legal consequences for distributively unfair model bias. Effective bias mitigation will require interdisciplinary teamwork among forensic scientists, AI engineers and developers, legal practitioners, and social scientists to ensure that technological systems are designed and deployed in ways that equitably impact social relations.

D. Privacy and Surveillance Concerns

The use of AI technology capable of remotely sensing the environment raises significant privacy and civil liberties issues. Persistent aerial surveillance, satellite monitoring of privately owned parcels of land, biometric data collection in public places, crime-prediction systems, and other forms of surveillance technology provide means to collect data on people and communities. Protecting the individual right to privacy while enjoying the public safety benefits of these technologies will require strong legal and regulatory frameworks. Some of these safeguards include judicial oversight of surveillance, strict policies on data retention and data minimization, judicial oversight of use and clarifications on the use of opaque systems, and transparency about the limits of the systems themselves and the ways they are used. Ethical self-governance must be in place to mitigate the capital erosion of public trust in forensics and law enforcement, as well as the potential abuse of such technologies and the public trust.

E. Technical Limitations and System Reliability

AI-enhanced remote sensing systems are, in theory, very capable. However, despite their promise, all systems will be impacted to some degree by fundamental technical issues, such as the issues of quality and diversity in the training data, the transparency in explaining the decisions made by the models, susceptibility to adversarial attack or manipulation, sensitivity to and suffering from particular environmental conditions, and requiring excessive amounts of computational power. Few, if any, enhancements are possible to the forensic system and its processes for dealing with remote sensing systems or other systems, since the processes will not be adaptable to maintaining meaningful human oversight, strict protocols for testing and validation, and transparency in the systems themselves.

Operating in such constrained environments means the system will require as much, if not more, formal training, education, and guidance in AI systems to derive plausible and pragmatic solutions [45].

Technology	Key Advantages	Key Limitations
UAV-Based Documentation	Rapid deployment, cost-effective operation, comprehensive spatial coverage, non-intrusive evidence collection, high-resolution 3D modeling	Weather dependency, limited battery endurance, regulatory constraints in controlled airspace, privacy concerns, and the requirement for trained operators
Hyperspectral Imaging	Detection of evidence invisible to the naked eye, high accuracy in material discrimination and remains analysis, strong potential for large-area scanning, chemical and biological identification.	High sensor and operational costs, susceptibility to atmospheric interference, dependence on high-quality training data, and limitations imposed by spectral range
Synthetic Aperture Radar (SAR)	Day-and-night operation, weather-independent imaging, extensive area coverage, and effective detection of large-scale illegal activities	Very high satellite and processing costs, resolution constraints for fine details, potential for false alarms, and a requirement for specialized expertise
Thermal Imaging	Effective operation in complete darkness, no artificial illumination required, rapid detection of heat signatures, useful for search and recovery operations	Sensitivity to ambient temperature variations, inability to image through solid objects, variable image quality, and challenges in contextual interpretation
GIS-Based Analysis	Advanced spatial pattern recognition, scalability across large datasets, multi-layer data integration, predictive and prescriptive analytical capabilities	Strong dependence on data quality and completeness, risk of algorithmic bias, reliance on historical datasets, and significant computational requirements
Deep Learning Image Analysis	Automated large-scale analysis, high accuracy in classification and detection, rapid processing, and effective identification of hidden manipulations	Limited interpretability of decision-making (“black-box” behavior), vulnerability to adversarial attacks, risk of data-driven bias, and requirement for large and diverse training datasets

Table 3. Comparative assessment of strengths and constraints of AI-driven remote sensing and analytical techniques applied in modern forensic investigations.

XI. CONCLUSION

This review shows that computer science and remote sensing have changed the way that forensic investigations are conducted through more accurate, efficient, non-invasive, and scalable evidence detection and analysis. The combination of UAVs, hyperspectral imaging, synthetic aperture radar, thermal imaging, GIS, deep learning, and multi-sensor data fusion enables forensic practitioners to precisely document complex crime scenes, identify previously hidden evidence, and reconstruct events to support investigative and judicial decision-making. The studied applications demonstrate improvements in safety, impartiality, and evidentiary reliability. Innovations in computer science and remote sensing will need to tackle legal admissibility, privacy and surveillance, algorithm bias, evidence interoperability, and technological reliability. All of these need to be addressed across borders and disciplines. New remote sensing methods, analytical computers, sensor swarms, and autonomous systems are expected to widen the scope of forensic investigations. The technologies should also uphold humane values and the judicial principles of forensic science.

REFERENCES

[1] C. de Bruyn, K. Ralebitso-Senior, K. Scott, H. Panter, and F. Bezombes, "Search, Detect, Recover: A Systematic Review of UAV-Based Remote Sensing Approaches for the Location of Human Remains and Clandestine Graves," Drones 2025, Vol. 9, Page 674, vol. 9, no. 10, p. 674, Sep. 2025, doi: 10.3390/DRONES9100674.

[2] S. Salcedo-Sanz et al., "Machine learning information fusion in Earth observation: A comprehensive review of methods, applications and data sources," Information Fusion, vol. 63, pp. 256–272, Nov. 2020, doi: 10.1016/j.inffus.2020.07.004.

[3] M. Laverde-Barajas et al., "ST-CORAbico: A Spatiotemporal Object-Based Bias Correction Method for Storm Prediction Detected by Satellite," Remote Sensing 2020, Vol. 12, Page 3538, vol. 12, no. 21, p. 3538, Oct. 2020, doi: 10.3390/RS12213538.

[4] "Special focus on deep learning in remote sensing image processing - ProQuest." Accessed: Dec. 16, 2025. [Online]. Available: https://www.proquest.com/docview/2918621855?pq-origsite=gscholar&fromopenview=true&sourcetype=Scholarly%20Journals

[5] J. Kaivosoja et al., "Reference Measurements in Developing UAV Systems for Detecting Pests, Weeds, and Diseases," Remote Sensing 2021, Vol. 13, Page 1238, vol. 13, no. 7, p. 1238, Mar. 2021, doi: 10.3390/RS13071238.

[6] H. Zhang, H. Liang, T. Ni, L. Huang, and J. Yang, "Research on Multi-Object Sorting System Based on Deep Learning," Sensors 2021, Vol. 21, Page 6238, vol. 21, no. 18, p. 6238, Sep. 2021, doi: 10.3390/S21186238.

[7] P. Grigusova et al., "Area-wide prediction of vertebrate and invertebrate hole density and depth across a climate gradient in chile based on uav and machine learning," Drones, vol. 5, no. 3, p. 86, Sep. 2021, doi: 10.3390/DRONES5030086/S1.

[8] P. Erbacher, L. Soulier, and L. Denoyer, "State of the Art of User Simulation approaches for conversational information retrieval," CEUR Workshop Proc, vol. 2911, pp. 32–37, Jan. 2022, Accessed: Dec. 16, 2025. [Online]. Available: https://arxiv.org/pdf/2201.03435

[9] N. Mohammad, R. Ahmad, A. Kurniawan, and M. Y. P. Mohd Yusof, "Applications of contemporary artificial intelligence technology in forensic odontology as primary forensic identifier: A scoping review," Front Artif Intell, vol. 5, p. 1049584, Dec. 2022, doi: 10.3389/FRAI.2022.1049584/FULL.

[10] D. Sauter, G. Lodde, F. Nensa, D. Schadendorf, E. Livingstone, and M. Kukuk, "Validating Automatic Concept-Based Explanations for AI-Based Digital Histopathology," Sensors 2022, Vol. 22, Page 5346, vol. 22, no. 14, p. 5346, Jul. 2022, doi: 10.3390/S22145346.

[11] A. N. Sazaly, M. F. M. Ariff, and A. F. Razali, "3D Indoor Crime Scene Reconstruction from Micro UAV Photogrammetry Technique," Engineering, Technology & Applied Science Research, vol. 13, no. 6, pp. 12020–12025, Dec. 2023, doi: 10.48084/ETASR.6260.

[12] [12] N. E. Mohd Sabri et al., "A scoping review on drone technology applications in forensic science," SN Applied Sciences 2023 5:9, vol. 5, no. 9, pp. 233-, Aug. 2023, doi: 10.1007/S42452-023-05450-4.

[13] [13] O. Ramírez-Ayala, I. González-Hernández, S. Salazar, J. Flores, and R. Lozano, "Real-Time Person Detection in Wooded Areas Using Thermal Images from an Aerial Perspective," Sensors (Basel), vol. 23, no. 22, p. 9216, Nov. 2023, doi: 10.3390/S23229216.

[14] [14] B. Janga, G. P. Asamani, Z. Sun, and N. Cristea, "A Review of Practical AI for Remote Sensing in Earth Sciences," Remote Sensing 2023, Vol. 15, Page 4112, vol. 15, no. 16, p. 4112, Aug. 2023, doi: 10.3390/RS15164112.

[15] T. Lu, C. Li, W. Zhou, and Y. Liu, "Fuzzy Assessment of Ecological Security on the Qinghai–Tibet Plateau Based on Pressure–State–Response Framework," Remote Sensing 2023, Vol. 15, Page 1293, vol. 15, no. 5, p. 1293, Feb. 2023, doi: 10.3390/RS15051293.

[16] Z. Jianqiang et al., "Identification of Bloodstains by Species Using Extreme Learning Machine and Hyperspectral Imaging Technology," Appl Spectrosc, vol. 78, no. 9, pp. 942–950, Sep. 2024, doi: 10.1177/00037028241261727;WGROUP:STRING:PUBLICATION.

[17] X. Ding, Y. Nie, J. Yao, J. Tang, and Y. Lang, "Forensic research of satellite images forgery: a comprehensive survey," Artificial Intelligence Review 2024 57:9, vol. 57, no. 9, pp. 253-, Aug. 2024, doi: 10.1007/S10462-024-10909-W.

[18] A. A. Laghari, A. K. Jumani, R. A. Laghari, H. Li, S. Karim, and A. A. Khan, "Unmanned aerial vehicles advances in object detection and communication security review," Cognitive Robotics, vol. 4, pp. 128–141, Jan. 2024, doi: 10.1016/J.COGR.2024.07.002.

[19] "(PDF) AI and GIS for Crime Mapping and Kidnapping Mitigation: A Case Study of Ondo State, Nigeria." Accessed: Dec. 17, 2025. [Online]. Available: https://www.researchgate.net/publication/382241622_AI_and_GIS_for_Crime_Mapping_and_Kidnapping_Mitigation_A_Case_Study_of_Ondo_State_Nigeria

[20] A. U. Rehman, L. Zhang, M. M. Sajjad, and A. Raziq, "Multi-Temporal Sentinel-1 and Sentinel-2 Data for Orchards Discrimination in Khairpur District, Pakistan Using Spectral Separability Analysis and Machine Learning Classification," Remote Sensing 2024, Vol. 16, Page 686, vol. 16, no. 4, p. 686, Feb. 2024, doi: 10.3390/RS16040686.

[21] C. de Bruyn, K. Ralebitso-Senior, K. Scott, H. Panter, and F. Bezombes, "Search, Detect, Recover: A Systematic Review of UAV-Based Remote Sensing Approaches for the Location of Human Remains and Clandestine Graves," Drones 2025, Vol. 9, Page 674, vol. 9, no. 10, p. 674, Sep. 2025, doi: 10.3390/DRONES9100674.

[22] M. S. Balbudhe, B. S. K. Shetty, N. Arun Kumar, D. Singh, and A. I. Sherekar, "Crime scene reconstruction: a scoping review," Egyptian Journal of Forensic Sciences 2025 15:1, vol. 15, no. 1, pp. 79-, Oct. 2025, doi: 10.1186/S41935-025-00495-5.

[23] F. Li et al., "Dark Ship Detection via Optical and SAR Collaboration: An Improved Multi-Feature Association Method Between Remote Sensing Images and AIS Data," Remote Sensing 2025, Vol. 17, Page 2201, vol. 17, no. 13, p. 2201, Jun. 2025, doi: 10.3390/RS17132201.

[24] W. Villegas-Ch, R. Gutierrez, and A. Maldonado Navarro, "Artificial intelligence techniques for enhancing accuracy and efficiency in digital forensic analysis," Discover Artificial Intelligence 2025, Dec. 2025, doi: 10.1007/S44163-025-00729-4.

[25] S. Lu et al., "Vision Foundation Models in Remote Sensing: A Survey," IEEE Geosci Remote Sens Mag, vol. 13, no. 3, pp. 190–215, Aug. 2024, doi: 10.1109/MGRS.2025.3541952.

[26] M. Koopman, Q. Milliet, and C. Champod, "A review of predictive modelling and drone remote sensing technologies as a tool for detecting clandestine burials," Forensic Sci Int, vol. 367, p. 112375, Feb. 2025, doi: 10.1016/J.FORSCIINT.2025.112375.

[27] K. Yang, M. Zhu, X. Guo, Y. Zhang, and Y. Zhou, "Stochastic Potential Game-Based Target Tracking and Encirclement Approach for Multiple Unmanned Aerial Vehicles System," Drones 2025, Vol. 9, Page 103, vol. 9, no. 2, p. 103, Jan. 2025, doi: 10.3390/DRONES9020103.

[28] E. Pérez, A. Sánchez-Hermosell, and P. Merchán, "TLSynth: A Novel Blender Add-On for Real-Time Point Cloud Generation from 3D Models," Remote Sensing 2025, Vol. 17, Page 421, vol. 17, no. 3, p. 421, Jan. 2025, doi: 10.3390/RS17030421.

[29] P. Dahiya and A. Bhatia, "Exploring Geo-Forensic Applications in Coastal Crime Scene Detection: The Role of Remote Sensing Technologies," Environ Forensics, Nov. 2025, doi: 10.1080/15275922.2025.2594980;JOURNAL:JOURNAL:UENF20;WGROUP:STRING:PUBLICATION.

[30] "Predictive Policing: The Role of AI in Crime Prevention," International Journal of Computer Applications Technology and Research, Oct. 2024, doi: 10.7753/IJCATR1310.1006.

[31] P. B. Bandara, O. D. Jayarathna, D. T. Hewage, N. P. Bandara, D. Pandithage, and D. Siriwardana, "Blockchain-Based Chain of Custody Evidence Management System for Digital Forensic Investigations," ICAC 2023 - 5th International Conference on Advancements in Computing: Technological Innovation for a Sustainable Economy, Proceedings, pp. 703–708, 2023, doi: 10.1109/ICAC60630.2023.10417307.

[32] Z. Wang et al., "Ethical Framework to Assess and Quantify the Trustworthiness of Artificial Intelligence Techniques: Application Case in Remote Sensing," Remote Sensing 2024, Vol. 16, Page 4529, vol. 16, no. 23, p. 4529, Dec. 2024, doi: 10.3390/RS16234529.

[33] F. Dadrass Javan, F. Samadzadegan, A. Toosi, and M. van der Meijde, "Unmanned Aerial Geophysical Remote Sensing: A Systematic Review," Remote Sens (Basel), vol. 17, no. 1, p. 110, Jan. 2025, doi: 10.3390/RS17010110/S1.

[34] A.-A. Ulmˇ Amei, T. D'adamo, C.-E. Vasile, and R. Hobincu, "Human Detection in UAV Thermal Imagery: Dataset Extension and Comparative Evaluation on Embedded Platforms," Journal of Imaging 2025, Vol. 11, Page 436, vol. 11, no. 12, p. 436, Dec. 2025, doi: 10.3390/JIMAGING11120436.

[35] M. Ahmad, "Predictive Policing - Leveraging CCTV Data and AI for Crime Hotspots," Theses, Jan. 2025, Accessed: Dec. 17, 2025. [Online]. Available: https://repository.rit.edu/theses/12193

[36] B. Janga, G. P. Asamani, Z. Sun, and N. Cristea, "A Review of Practical AI for Remote Sensing in Earth Sciences," Remote Sensing 2023, Vol. 15, Page 4112, vol. 15, no. 16, p. 4112, Aug. 2023, doi: 10.3390/RS15164112.

[37] N. Kazanskiy, R. Khabibullin, A. Nikonorov, and S. Khonina, "A Comprehensive Review of Remote Sensing and Artificial Intelligence Integration: Advances, Applications, and Challenges," Sensors 2025, Vol. 25, Page 5965, vol. 25, no. 19, p. 5965, Sep. 2025, doi: 10.3390/S25195965.

[38] © June and 2025| Ijirt |, "UAV-Acquired 3D Reconstruction of Crime Scene for comprehensive Forensic Crime Scene Documentation," INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN TECHNOLOGY, vol. 12, 2025.

[39] M. Zulfiqar, M. Ahmad, A. Sohaib, M. Mazzara, and S. Distefano, "Hyperspectral Imaging for Bloodstain Identification," Sensors 2021, Vol. 21, Page 3045, vol. 21, no. 9, p. 3045, Apr. 2021, doi: 10.3390/S21093045.

[40] M. Yasir, M. Bozzi, L. Perregrini, S. Bistarelli, A. Cataldo, and S. Bellucci, "Highly tunable and large bandwidth attenuator based on few-layer graphene," 2017 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications, IMWS-AMP 2017, pp. 1–3, Jan. 2018, doi: 10.1109/IMWS-AMP.2017.8247336.

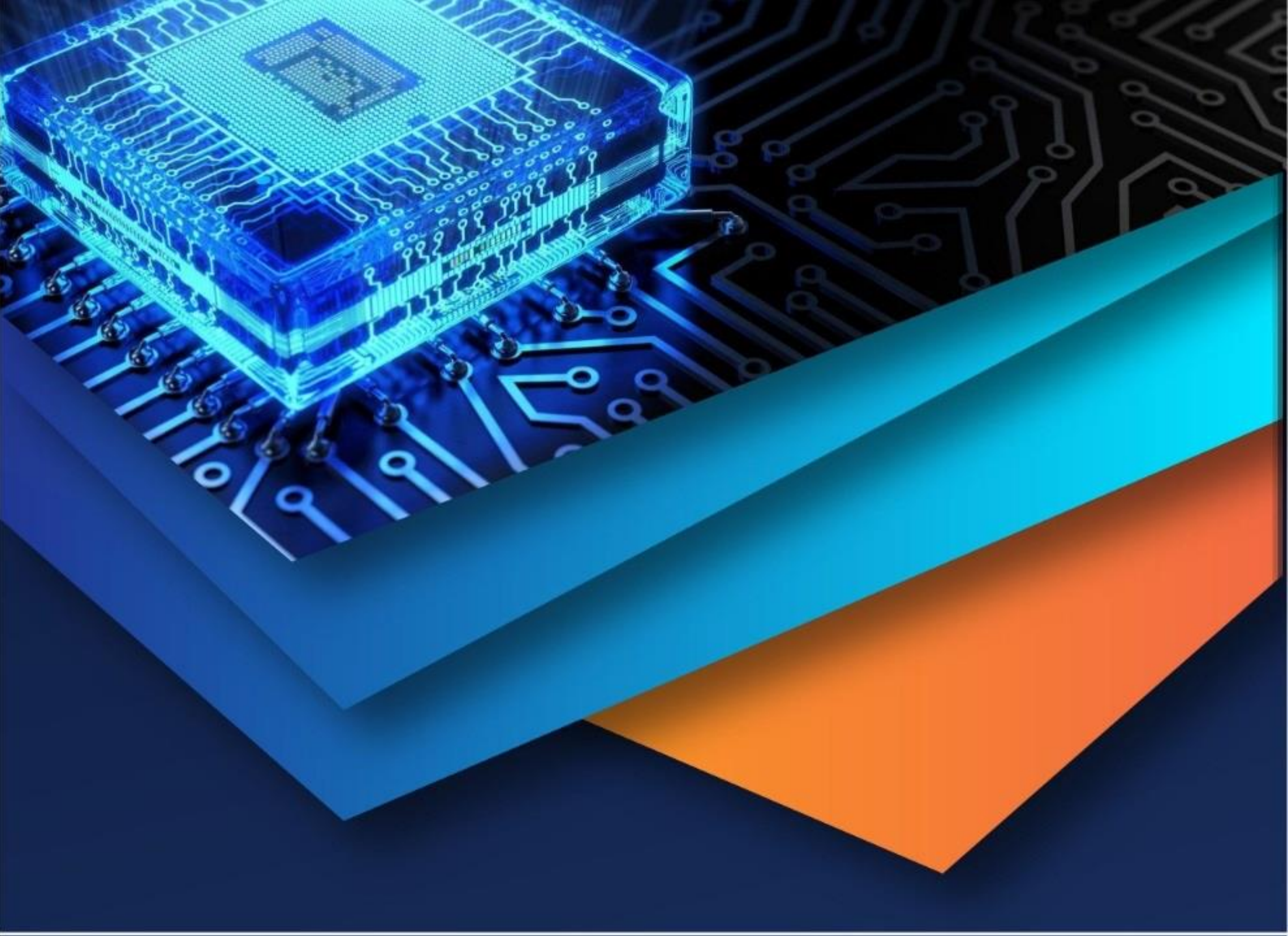
[41] "Detection of cadaveric remains by thermal imaging cameras." Accessed: Dec. 17, 2025. [Online]. Available: https://www.researchgate.net/publication/287634205_Detection_of_cadaveric_remains_by_thermal_imaging_cameras?utm_source=chatgpt.com

[42] J. C. Allen, "Investigative advising: a job for Bayes," Crime Science 2014 3:1, vol. 3, no. 1, pp. 7-, Apr. 2014, doi: 10.1186/2193-7680-3-7.

[43] A. Kuwahata et al., "Magnetic Nanoparticle Detection by Utilizing Nonlinear Magnetization for Sentinel Lymph Nodes of Breast Cancer Patients," IEEE Trans Magn, vol. 57, no. 2, Feb. 2021, doi: 10.1109/TMAG.2020.3010641.

[44] M. Reichstein et al., "Deep learning and process understanding for data-driven Earth system science," Nature, vol. 566, no. 7743, pp. 195–204, Feb. 2019, doi: 10.1038/S41586-019-0912-1;TECHMETA.

[45] B. Janga, G. P. Asamani, Z. Sun, and N. Cristea, "A Review of Practical AI for Remote Sensing in Earth Sciences," Remote Sensing 2023, Vol. 15, Page 4112, vol. 15, no. 16, p. 4112, Aug. 2023, doi: 10.3390/RS15164112.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY