Using Thermal Cameras in Drones in the Field of Digital Forensics: A Review

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Abstract:

The advancement of drones has significantly expanded their application in the field of digital forensics through the integration of thermal camera technology. The thermal cameras mount on drones to detect heat signatures. The thermal cameras are highly effective for identifying human presence and helpful in detecting wildlife activities. This review shows the role of using thermal cameras in drone forensics, with a focus on human detections in wildlife and in covert operations. In wildlife, thermal cameras play an important role in detecting illegal activities and in nighttime activities. The technology of using thermal cameras will help in real-time monitoring of animals and track their activities. In covert operations the thermal cameras being used in the drones provide an advantage by detecting hidden individuals during nighttime or low-visibility conditions by using the thermal cameras in drones to identify human heat patterns without direct visual contact, it can also help in tracking the suspect and post-incident crime scene analysis while minimizing risk to forensic investigators. In the digital forensics point of view, the thermal images and videos captured by drones serve as important and valuable digital evidence. The data that we get from the thermal cameras can give information such as time, location, and particular information that can help in the wildlife and in the covert operation by the military and Secret agencies.

Keywords: Drones forensics, Thermal cameras, Wildlife, Covert operations, Heat, Body Temperature.

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1.Introduction:

Digital forensics has evolved significantly with the growth of advanced sensing and surveillance technologies with the thermal cameras in the wildlife and covert operations. The thermal imaging or videos can help in identifying body temperature, which can help in tracking the suspect from the low visibility, and it can help in wildlife the thermal cameras with drones can help in the monitoring of animals and tracking their activities. The drones also known as UAVs (Unmanned aerial vehicles). The drones have been increasingly adopted in forensics investigations due to their speed, mobility and ability to access the long-range areas.

There was different types of sensors installed in drones which can be help in the accessing location and with thermal cameras it detect heat emitted by humans, animals, and any objects. This allows forensic investigators to identify living bing and recently activity. the thermal cameras can help in the identification of the objects, heat elements and animals locations in the darker or zero visibility. Most of the covert operations will use thermal cameras to detect the suspect location in night times.

The use of thermal cameras in drones forensics plays a important role in the detection of human presence during covert operation. Heat signatures or small amount of heat residues from the cameras where it can help in the investigators to locate hidden individual, tracking moment patterns and suspects, and monitor sensitive areas while maintaining operational safety. The thermal cameras can help in the reduction of the ground-based intervention and help in redacting in risk while covert operations. The thermal drones help in the wildlife forensic for identifying illegal activities such as poaching, tracking animals in forest. From a digital forensic point of view, thermal images and videos collected by thermal drones helps in important digital evidence, which can be in the detection of human in the covert operation or in the wildlife forensics with the help in location, time, and flight parameters.

This research paper shows the importance of thermal cameras in drones in terms of digital forensics.

2. Literature review:

Thermal cameras are used in imaging and videos with the drones. Where the thermal cameras are mounted on drones are used in many fields because of the usage of thermal cameras it can detect the heat instead of visible light. Unlike normal cameras, thermal cameras can work at night and in poor visibility conditions such as smoke, dust, fog, forests and covert operations. Because of this advantage, thermal cameras mounted on drones are becoming very useful in digital forensic, especially for crime scene investigations, searching and rescue, wildlife forensic and covert surveillance operations.(1)

One important study in this area was conducted by Park and Yeon(2021), who focused on detection human and identification their posture using thermal images captured by a drone. Their research showed their posture using thermal images cameras mounted on drones can successfully detected humans during both day and night, even in dangerous and mountainous environments. This is especially useful in situations where sending forensic teams on the goound risky or time-consuming.(2)

In their work, the authors used simple imaging processing techniques to separate human heat signatures from the background. To reduce false detections, they applied the head signatures to detect the object. This helped improve accuracy, as thermal cameras often have low resolution and limited details compared to normal images. Many previous studies on thermal drones mainly focused on detecting or tracking humans and animals. However, they did not provide additional information about human behaviors or conditions. This is important because drones have limited processing power and battery life, especially during long forensic missions.(2)

From a digital forensic point of view, thermal drones can act as supporting digital evidence by showing the presence, movement, and behavior of human in hard-to-teach locations. Thermal drones are also helpful in wildlife crime detections, border surveillance, covert operations. The main challenges such as environmental and overlapping heat sources.(4)

The research of the thermal cameras on drones are powerful tool for modern digital forensic. The studies of thermal cameras using Dones clearly useful for the human detection.

3. Methodology:

This paper was approached using a review-based research methodology to observe the existing research papers articles and information on the topic of using thermal cameras in drones in the field of digital forensic. The main objective of this review paper is to analyses the importance of thermal caameras in dones in the wildlife and covert operations using this thermal cameras techniques as well as comparing them to the new and emerging machine learning based approaches and techniques. a systematic search was conducted using acadamic database and resources like google scholar, IEEEE Xplore, springerlink, scienceDirect, researchGate. Keywords used to fine the content including digital forensic, thermal cameras, wildlife forensics, covert operations, drone forensics, heat, body temperature, images and videos, night-vision, nighttime.

Conference papers, research papers, journal articals that were observed analysed understood and categorized based on the content needed like based on detections techniques used, that included thermal imaging thermal video processing methods. A comparative study was performed to identify the gaps, strengths, challenges, and limitations.

4. Fundamentals of thermal cameras and drones technology:

4.1 Thermal cameras basic principle:

Thermal cameras operate by detecting infrared radiation emitted by objects as a function of their temperature. Unlike normal cameras that depend on reflected visible light, thermal cameras capture heat energy, allowing them to function effectively in low-light or no light conditions, including nighttime, fog, smoke and dense vegetation. This characteristics makes thermal cameras highly valuable when mounted on drones for digital forensics investigations.

In wildlife forensic thermal cameras mounted on drones enables non-intrusive monitoring of animals in their natural habitats. They are widely applied for detecting poaching activities, tracking animals movement, locating injured or hidden wildlife, and conducting population assessment,

especially during nighttime or in forested environments. The clear temperature contrast between animals and their surrounding allows reliable detection without disturding wildlife.

For covert operations human detection, thermal cameras play a crucial role in military, intelligence, and law-enforcement operations. Humans emit a consistent heat signature that can be identified even when individual attempt to conceal themselves using camouflage or operate in darkness. From a digital forensic perspective, thermal footage collected by drones serves as valuable digital evidence, supporting surveillance, event reconstructions, and post operations analysis.

4.2 Drones technology

The advancements in drones technology have significantly improved digital forensic investigations, especially when integrated with thermal cameras systems. Drones equipped with thermal cameras enable non-intrusive evidence collection in challenging environments such as forests, border regions, and restricted zones. This technology is particularly valuable in wildlife forensic and covert operations, where traditional investigation method are often limited. The thermal cameras system used drones technology for detect infrared radiations emitted by living being and object, allow the identification of human and animals even in darkness, fog or smoke. in wildlife forensic thermal cameras technology helps in locate poached animals, track animals, and identify illegal hunting activities. In covert operations, thermal sensors are used to detect hidden human movement, temporary shelters, and unauthorized cams without revealing the drones presence.

5. Applications of thermal drones in digital forensic with wildlife and covert operations:

Thermal drones, equipped with infrared cameras, have emerge as powerful tools in the filed of digital forensics. These drones capture heat signatures emitted by living being and objects, enabling investigations to detect , monitor, and document activities that are otherwise invisible to the naked eye. The integration of thermal cameras with drones enhance evidence collection, situational awareness, and forensic analysis, particularly in wildlife and covert operations.

5.1 Wildlife forensics and anti-poaching investigations:

One of the most significant applications of thermal drones in digital forensic is wildlife protection. Thermal cameras can detect animals and humans in dense forests, grasslands, and protected reserves during both day and night. This capability is crucial for identifying illegal hunting, poaching activities and unauthorized human movements in restricted wildlife zones. Thermal data collected by drones can be stored as digital evidence, helping forensic experts analyze patterns of poaching, track suspects, and support legal processing. Additionally, thermal drones assist in locating injured or trapped animals, contributing to conservation effects.

5.2 Covert operations:

Thermal drones play a vital in covert operations conducted by military and secret agencies. Unlike visible-light cameras, thermal cameras does not rely on external lighting and can detect hidden border areas, tracking suspects, and identifying concealed threats. In digital forensics, thermal recording serve as critical evidence to reconstruct cover movements and analyze suspect behavior without direct physical confrontations. It can help in searching, detection and tracking of humans. The digital evidence collection like photos, videos, locations, and timing which can help in the digital forensics.

6. Comparative analysis of existing studies:

6.1 Sensor resolution:

Sensor resolution refers to the number of pixels in a thermal camera and directly affects detection capability. Higher-resolution thermal sensors can capture finer temperature details, making it easier to distinguish human or animals from the background. Low-resolution sensors often produce blurred thermal images, leading to misidentification, especially when targets are partially Hennen by vegetation or terrain. In digital forensic applications, poor resolution can reduce evidentiary value because precise shape, movement detection, higher resolution improve reliability but also increass cost, payload weight, and power consumption.

6.2 Detection accuracy:

Detection accuracy depends on sensor quality, altitude, image processing algorithms, and target behavior. Thermal cameras may confuse warm object such as rocks, vehicles, or animals with

humans, leading to false positives. Similarly, animals reasting or humans wearing insulating clothing may produce weak thermal signatures**.**

7. Challenges and limitations identified in literature:

7.1 Environmental and technical constrains:

The environmental challenges thermal cameras work by decting heat differences. When the surrounding temperature is hight, such as during daytime or in hot climates. The heat difference between human, animals, and the environment becomes very small. This make detection difficult. Many studies mentions that detection works better at night or in Cooler weather.

Weather conditions also performance. Rain, fog, high humidity, and strong winds reduce the quality of thermal images and make drone flight unstable. Dense forests, tall grass, and thick vegetation can block heat signals, which limits the detections of humans or animals in wildlife areas.

Technical challenges one of major technical limitation is the low resolution of thermal cameras used on drones. compared to normal cameras, thermal camerass often lack clear details, making it hard to correctly identify or animals from a distance.

Battery life is an major problem. Drones carrying thermal cameras use more power, which reduces flight time and limits the area that can be covered during forensic investigations. Communication probllems, such as weak signals in remote areas, can also affect real-time data transmission. False detection is also reported in literature. Warm objets like rocks, vehicles, or buildings can be mistaken for human or animals. Because of this, expert analysis or advanced software is often required to correctly interpret thermal data.

8. Research gaps:

8.1 low visibility and dense canopy challenges:

Thermal cameras penetrate darkness but still struggle under dense forest canopies and layed vegetations common in wildlife. The main gap is insufficient research on enhancing thermal signal interpretation under heavy occlusion for forensic purposes.

8.2 Human factors and operator training:

Advanced thermal data interpretation requires expertise. The main gap in this is insufficient research on training protocols and human-machine interfaces to support forensic investigation teams using tharmal drones data.

9. Future directions:

the use of thermal cameras mounted on drones in digital forensic is still an evolving area, especially in the context of wildlife monitoring directions can enhance their effectiveness, reliability, and forensic value.

9.1 Improved thermal sensor technology:

Research is needed to develop higher-resolution, lightweight, and energy-efficient thermal sensors. Enhanced sensors would allow longer flight times and more accurate detection od small animals or well-camouflaged humans, which is critical in anti-poaching operations and muilitary reconnaissance.

9.2 Real-time and autonomous operations:

Developing autonomous capable of real-time thermal analysis and adaptive flight paths will significantly improve rapid response in wildlife animals detection and covert operations missions.

10. Conclusion:

This review paper emphasizes the significant role of thermal camera-equipped drones in advancing digital forensics investigations, particularly in wildlife forensic and covert operations. By detecting heat signatures rather than visible light, thermal cameras enable effective identification of human and animals in low-visibility conditions such as nightitme, fog, dense vegetation, and restricted environments. This capability make thermal drones highly or monitoring illegal activities, anti-poaching operations, and suspect detection while reducing to forensic personnel.

In wildlife forensics, thermal drones support non-intrusive animal monitoring, tracking of poachers, and evidence collection in in protected areas. In covert operations, they provide a tactical advantage by detecting concealed individual and supporting surveillance and post-incident forensics analysis. From a digital forensic perspective, thermal images and videos such as crucial digital evidence, supported by metadata such as time, locations, and flight parameters.

Despite these advantages, challenges remain , including environmental interference, limited through improved sensor technology, real-time analysis, and enhanced operator training will further strengthen then forensic reliability and effectiveness of thermal drones systems.

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