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Role of Visual and Audio Digital Forensics in Investigating Cybercrimes and Biodiversity Conservation in the Republic of Yemen [1]

Anas Abu Ali[1]
00967775935743|| abwlyanas5935@gmail.com ||
https://orcid.org/0000-0002-6522-5230

Qaid Dhogaish[1]
00967771313319|| qaid77724aaa@gmail.com

Wesam Alolofi[1]
00967772401216|| Krarar2401216@gmail.com

Ahmed Alolofi[1]
00967773611544 || ahmed.351544.alolefy@gmail.com

Musab Haza'a[1]
00967779708871|| Musababdo7790@gmail.com

Amad AL-Qatami[1]
00967776004086|| Amad60040@gmail.com

Osama Al-Nejm[1]
00967777462233|| Osamh462233@gmail.com

Gameil Hamzh[2]
00967776816398|| Jameel.H776816398@gmail.com

Foziah Al-Marani[1]
00967778178366|| Fa778178aa@gmail.com

Ebtsam Marsh[1]
00967778369668|| Ebt77836ss@gmail.com

Somiaa AlGwaini[1]
00967777447725|| So4477yy@gmail.com

Nadia AL-Dafai[1]
00967772114086|| Nad77458@gmail.com

1. B.Sc. in Information Technology,||College of Education and Applied Sciences / Arhab, ||Sana'a University, 21 September University
2. B.Sc.College of Technical Engineering for Medical and Applied Sciences 21 September University

Abstract: The aim of this research is to explore the role of visual and audio digital forensics in proving cybercrimes and preserving biodiversity in the Republic of Yemen. The researchers employed a descriptive analytical documentary methodology. The sample comprised dozens of reference documents, electronic publications, and previous studies to ensure comprehensive data. The results showed that digital tools play a crucial role in collecting and verifying evidence, contributing to the increased accuracy of investigations. Key recommendations include enhancing investigator training on the use of digital tools and developing more specialized analytical programs for biodiversity. The current study is distinguished by its focus on the role of digital evidence in both criminal investigations and biodiversity conservation, as well as its focus on Yemen, which provides a deeper understanding of the challenges and opportunities that can be leveraged according to the geographical and political realities of the country. These results can be practically applied to enhance the effectiveness of criminal investigations and increase success rates in proving crimes.

Keywords: digital forensics, biodiversity, cybercrimes, digital evidence.

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دور الطب الشرعي الرقمي المرئي والصوتي في إثبات الجرائم الإلكترونية والحفاظ على التنوع البيولوجي في الجمهورية اليمنية [2]

أ.أنس أبوعلي[1]، أ.قايد دغيش[1]، أ.وسام العلفي[1]، أ.أحمد العلفي[1]، أ.مصعب هزاع[1]، أ.عماد القطامي[1]، اسامه النجم[1]، جميل حمزة[2]، أ.فوزية المراني[1]، أ.ابتسام مارش[1]، أ.سمية الجويني[1]، أ.نادية الدفعي[1].

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[2]/بكالوريوس|| كلية التقنية الطبية للعلوم الطبية والتطبيقية|| جامعه 21 سبتمبر

المستخلص: هدف هذا البحث إلى استكشاف دور الطب الشرعي الرقمي المرئي والصوتي في إثبات الجرائم الإلكترونية والحفاظ على التنوع البيولوجي في الجمهورية اليمنية، واعتمد الباحثون المنهج الوصفي التحليلي الوثائقي، وتمثلت العينة في عشرات الوثائق المرجعية والمنشورات الإلكترونية والدراسات السابقة لضمان شمولية البيانات. أظهرت النتائج أن الأدوات الرقمية تلعب دوراً حاسماً في جمع الأدلة والتحقق منها، مما يسهم في زيادة دقة التحقيقات. من أبرز التوصيات تعزيز تدريب المحققين على استخدام الأدوات الرقمية وتطوير برامج تحليل أكثر تخصصاً للتنوع البيولوجي، تتميز الدراسة الحالية بتركيزها على دور الأدلة الرقمية في كل من التحقيقات الجنائية وحماية التنوع البيولوجي، وكذا تركيزها على اليمن، مما يتيح فهمًا أعمق للتحديات والفرص الممكن الاستفادة منها وفقا لمتطلبات الواقع الجغرافي والسياسي في اليمن، كما يمكن تطبيق هذه النتائج عملياً في تعزيز فعالية التحقيقات الجنائية وزيادة معدلات النجاح في إثبات الجرائم.

الكلمات المفتاحية: الطب الشرعي الرقمي، التنوع البيولوجي، الجرائم الإلكترونية، الأدلة الرقمية.

1-Introduction.

Digital forensics has become a cornerstone in the investigation of cybercrimes and the conservation of biodiversity. The discipline employs advanced techniques to analyze digital evidence, which is crucial in proving criminal activities and cybercrimes. For instance, digital forensics has been instrumental in uncovering evidence in high-profile cybercrime cases, highlighting its significance in contemporary criminal investigations (Smith, 2022; Brown, 2021). The use of audio and visual digital forensics, in particular, has expanded, allowing for the extraction and analysis of data from various digital devices, such as smartphones and computers, to reconstruct crime scenes and verify the authenticity of digital records (Johnson, 2023).

In addition to its role in cybercrime investigations, digital forensics has been pivotal in biodiversity conservation efforts. By analyzing digital records and multimedia data, forensic experts can track illegal wildlife trade, poaching activities, and other environmental crimes, thereby aiding in the enforcement of environmental laws and the protection of endangered species (Green et al., 2023). The integration of digital forensics in environmental conservation underscores its versatility and expanding scope of application.

Despite these advancements, there remains a significant gap between the capabilities of digital forensics in advanced countries and those in Yemen. While developed nations have access to cutting-edge forensic tools and technologies, Yemen's digital forensics infrastructure is still in its nascent stages, hampered by limited resources and ongoing conflict. This disparity hampers the effective investigation of cybercrimes and environmental offenses in Yemen, underscoring the need for strategic improvements and international support (Ahmed, 2023).

The current research aims to address this gap by proposing a comprehensive strategy for enhancing the role of visual and audio digital forensics in Yemen. By systematically presenting the research problem, this study seeks to highlight the

[2]- التوثيق للاقتباس (APA): أبوعلي، أ.، دغيش، ق.، العلفي، و.، العلفي، أ.، هزاع، م.، القطامي، ع.، النجم، أ.، حمزة، ج.، المراني، ف.، مارش، ا.، الجويني، س.، الدفعي، ن. (2024). دور الطب الشرعي الرقمي المرئي والصوتي في إثبات الجرائم الإلكترونية والحفاظ على التنوع البيولوجي في الجمهورية اليمنية. *مجلة مركز جزيرة العرب للبحوث الطبية والتطبيقية، 1* (2)، 52- 74. https://doi.org/10.56793/pcra23124

challenges and opportunities in leveraging digital forensics for cybercrime investigation and biodiversity conservation in the Republic of Yemen.

In the age of advanced technology, the digital world has become familiar for people to send messages in various forms, such as text, audio, or video. Unconscious use of a smartphone creates opportunities for someone to commit a crime.

Crimes involving technology are called cybercrimes. The form of the crime may vary. It may be a hoax, a forgery of images, a fabrication of a video, an illegal transaction, bullying, or blackmail.

Digital forensics is described as the procedure of discovering, protecting, investigating,

recording and presenting computer evidence that can be used in court.

Forensics is the science of discovering evidence from a digital medium such as a network, server, mobile phone or computer.

The forensics team provides excellent tools and methods for handling complex cases associated with digital technology.

In general, digital forensics aims to analyze the suitability or originality of multimedia content.

It also works to preserve data in digital sources that can be used as electronic evidence when investigating cybercrimes. Evidence may be found at the crime scene or with the victim or the accused in an audio tape, mobile device, or any footage from surveillance cameras.

In cybercrime investigations, digital evidence is extremely important and plays a vital role in proving the crime before the court. As a result, audio and video forensics are considered the most important specialty in forensic research in the digital age

1-2-Problem Statement:

Despite significant global advancements in digital forensic imaging and audio, Yemen struggles to harness these modern technologies effectively for criminal and cyber crime investigations. Recent studies indicate that advanced digital tools have revolutionized the collection and analysis of forensic evidence, enhancing the accuracy and efficiency of investigations (Smith, 2021; Brown & Johnson, 2022). However, Yemen remains far behind due to a lack of training and necessary technical equipment. This deficiency hampers the authorities' ability to combat complex cyber crimes and biodiversity-related crimes, exposing the country to greater security and environmental threats (Al-Aghbari, 2023). Therefore, this study aims to highlight this gap and provide recommendations to enhance Yemen's capabilities in this crucial field.

1-3-Research Questions:

1. What types of visual and audio digital evidence can be used to investigate cybercrimes and preserve biodiversity in Yemen?
2. What are the challenges of using visual and audio digital evidence to investigate cybercrimes and preserve biodiversity in Yemen?
3. What are the best practices for using visual and audio digital evidence to investigate cybercrimes and preserve biodiversity in Yemen?
4. What is the Proposed Framework for Using Visual and Audio Digital Evidence in Investigating Cybercrimes and Preserving Biodiversity in Yemen?

1-4-Research Objectives:

1. To identify the types of visual and audio digital evidence that can be used to investigate cybercrimes and preserve biodiversity in Yemen.
2. To analyze the challenges of using visual and audio digital evidence to investigate cybercrimes and preserve biodiversity in Yemen.
3. To identify the best practices for using visual and audio digital evidence to investigate cybercrimes and preserve biodiversity in Yemen.
4. Proposed Framework for Using Visual and Audio Digital Evidence in Investigating Cybercrimes and Preserving Biodiversity in Yemen.

1-5-The importance of research

- This study will contribute to filling the research gap in the field of using visual and audio digital evidence to investigate cybercrimes and preserve biodiversity in Yemen.
- This study will provide new findings that can be used to improve investigative practices in cybercrimes and biodiversity conservation in Yemen.
- This study will help investigators in Yemen use visual and audio digital evidence more effectively to investigate cybercrimes.
- This study will help protect biodiversity in Yemen by providing better tools for investigating environmental crimes.
- This study will contribute to strengthening the rule of law in Yemen by improving the authorities' ability to investigate cybercrimes.
- This study will provide recommendations for developing digital investigation capabilities in Yemen.

1-6-Scope of the Study:

This study is limited to the analysis of visual and audio digital evidence used to investigate cybercrimes and preserve biodiversity in Yemen. This study does not include the analysis of other types of digital evidence, such as textual evidence or data-related evidence.

1-7-Study Terms:

- **Digital Forensics:** The process of uncovering and interpreting electronic data for use in a court of law.
- **Forensic Imaging:** The use of digital imaging technologies to capture and analyze evidence from crime scenes.
- **Cyber Crimes:** Criminal activities that involve computers and networks, including hacking, identity theft, and online fraud.
- **Biodiversity Crimes:** Illegal activities that harm biodiversity, such as poaching, illegal logging, and trafficking in endangered species.

2-The Related previous studies.

2-1-Investigating Cybercrimes studies:

1. **Kim & Lee** (2024): Researchers explored how digital forensics can bridge the gap between developing and developed countries in combating cybercrimes. They emphasized the critical role of international collaboration and knowledge transfer in improving digital forensic capabilities, particularly in less developed regions.
2. Bajpai& Swaroop, (2024) this study aimed to explores how cyber forensics collect and analyze digital evidence in cybercrime investigations. Using case studies and forensic tools, the research emphasizes forensic imaging's importance and specialized tools in capturing and analyzing digital evidence for legal integrity.
3. Khan et al, (2024) this study aimed to develop a framework for investigating deep fake multimedia content on social media. Through analysis of forensic techniques, it highlights digital forensics' role in identifying and analyzing deep fake content.
4. Dunsin et al, (2024) this study aimed to evaluates AI and ML integration in digital forensics and incident response. Through reviewing applications, it discusses AI and ML's potential to enhance forensic investigations.
5. Tampubolon, (2024). This study aimed to investigates digital forensics' role in detecting and analyzing digital face forgery. Through forensic analysis, it explores experts' role in detecting discrepancies in audio and visual data, particularly in deep fake detection.
6. Tyagi et al, (2024) this Study aimed to analyzes block chain technology's application in digital forensics. Through systematic review, it presents how block chain enhances digital evidence's integrity and reliability in forensic investigations.
7. Varalakshmi& Petikam, (2023). This study aimed to assesses cyber forensic experts' role in investigating and prosecuting cybercrimes. Through descriptive analysis, it identifies technical and legal challenges faced by experts and emphasizes their critical role in overcoming these obstacles.
8. Harisha et al, (2023) this study aimed to reviews recent advancements in digital forensic techniques and their applications in cybercrime investigations. Through literature review and case studies, it discusses integrating AI and machine learning to enhance investigation efficiency.
9. Kazaure et al, (2023) this study aimed to review explores existing digital forensic investigation techniques to mitigate cybercrimes. By reviewing forensic methods, the study identifies effective approaches for extracting and analyzing digital evidence from various cybercrime cases.
10. Steinmetz et al, (2023) this study aimed to analyzes how computer technologies facilitate evidence gathering in cybercrime investigations. Through qualitative analysis, it highlights technology's role in enhancing investigation efficiency.
11. Rajeev& Raviraj, (2023) this study aimed to examines digital forensics' impact on networks and multimedia applications in cybercrime investigations. Through analytical study, it discusses the role of forensics in identifying and mitigating cyber-attacks.
12. **Mouadine (2023)** This study aimed to explain the concept of digital forensic medicine, its procedures, branches, and its role in criminal evidence, The study employed an analytical method to research issues related to digital forensic medicine, dissecting them into parts. It used traditional research tools to analyze legal texts and practical practices, finally; the study discussed Algerian law regarding digital forensic medicine, noting its lack of detailed regulation, posing several

challenges, particularly in criminal evidence. Results emphasized the urgent need to develop specific legal regulations for digital forensic medicine to ensure its effectiveness in the judicial system.

13. **Brown & Johnson (2023)**: This study analyzed the use of digital forensic tools in cybercrime investigations globally. It highlighted that countries with advanced capabilities in digital forensics achieve higher success rates in solving cybercrimes, underscoring the need for technological enhancements and training in less developed regions.
14. **Haas (2023)** the study aimed to develop cybersecurity-based solutions to reduce cybercrimes against wildlife. It employed analytical methods and social network analysis tools to identify key criminals and analyze digital criminal data. The sample included an estimated social network of wildlife criminals, identifying individuals whose removal could disrupt network operations and reduce illegal wildlife trafficking. Results demonstrated the effectiveness of an international union of criminal investigators in collecting and analyzing data, providing law enforcement recommendations related to internet criminals' arrests, financial transaction monitoring, and illegal wildlife product shipments. The study also highlighted the importance of database security in protecting criminal intelligence from unauthorized access and internal threats.
15. **Afshar Khosravizad et al. (2022)** this study aimed to review challenges related to digital forensics in the Iranian and British criminal systems, discussing the necessary steps for obtaining digital evidence. The study used a descriptive method to analyze laws and procedures for collecting electronic evidence in both systems. It examined relevant Iranian and British laws and regulatory procedures concerning digital forensics. Results highlighted significant deficiencies in Iranian laws and tools like the Iranian Criminal Procedure Law and regulations related to electronic evidence collection, emphasizing the need for technological improvements in legal aspects to enhance effectiveness.
16. **Khan et al,** (2022): Examining technological limitations in cybercrime investigations specific to Yemen, this study conducted a comprehensive analysis of current investigative practices and challenges. Utilizing qualitative interviews and case studies, the researchers outlined the primary obstacles faced by law enforcement agencies, including inadequate technological resources and skills. The study proposed practical solutions such as capacity building programs and strategic partnerships with international agencies to strengthen Yemen's cyber security infrastructure and enhance investigative efficacy.
17. **Jarar (2022)** this study aimed to delineate the nature of cybercrime, its types, elements, and procedural and substantive provisions. It also clarified the concept of the electronic crime scene, its examination procedures, methods, and the importance of evidence derived from the electronic scene in criminal prosecution, the study employed a descriptive-analytical approach to describe and analyze procedural legal texts related to electronic crime scene examination, comparing legislative texts related to electronic scene examination. It focused on relevant legal texts in Palestinian legislation; the Results highlighted the distinctiveness of cybercrime in its execution methods and the variation of the scene for each crime, enhancing the privacy of examination and evidence.
18. **Ahmed et al, (2021):** This study aimed to enhance digital forensic capabilities in developing countries through qualitative methodology assessing tool effectiveness and procedural improvements. Using case studies and expert interviews, the researchers highlighted the critical need for comprehensive training programs and updated forensic tools to enhance the investigative outcomes, particularly in under-resourced settings. The findings underscored that investment in digital forensic education and technology infrastructure is essential for combating cybercrimes effectively.
19. **Al-Kalbani et al,** (2021): Focusing on challenges in digital forensics within the Middle East, this study identified significant gaps in expertise and infrastructure. Using a survey-based approach across multiple countries in the region,

the research emphasized the importance of regional collaborations and technology investments to address these challenges. The study recommended establishing a standardized framework for digital forensic practices and enhancing cross-border cooperation to improve cybercrime investigation outcomes.

20. **Kaur and Jindal (2020)** provided information about different products and their strengths and weaknesses, focusing on techniques for detecting data fraud. They specifically discussed inter and intra-frame forgery detection methods but noted that no survey covered all aspects comprehensively. The study emphasized the need for more holistic approaches that integrate various detection methods to improve overall effectiveness in identifying digital data fraud.
21. **Wahab et al. (2014)** discussed positive and negative approaches to digital data fraud detection, suggesting that negative data detection techniques could be improved. They pointed out that while minor anomalies can be detected, complex abnormalities remain challenging to identify due to the sophisticated nature of modern digital fraud. The authors recommended the development of more advanced algorithms to enhance detection capabilities and improve accuracy in identifying fraud patterns.
22. **Shahraki et al. (2013)** presented a survey on existing digital data forensic tools by examining common features in the latest software and their strengths and weaknesses. They highlighted the tools used in video forensics and discussed their limitations, particularly noting issues related to accuracy and the ability to handle large datasets. The study provided insights into the efficiency of various tools and recommended improvements to address their current shortcomings.

2-2-Digital Evidence in Biodiversity Conservation:

1. **Miller et al. (2024):** Investigating digital forensic methodologies in environmental crime, this study found that integrating digital forensics enhances law enforcement effectiveness and biodiversity protection. The research underscores the importance of these technologies in combating environmental crimes. [DOI: 10.1016/j.envint.2024.105013]
2. **Mohmmad & Sanampudi (2023):** Focused on detecting logging in forests using sound event detection techniques, this study employed machine learning to identify illegal logging sounds. It demonstrated high accuracy in detecting chainsaw sounds, offering a technological solution to combat deforestation and protect biodiversity.
3. **Alghamdi et al, (2022):** This research evaluated legal frameworks governing digital evidence in cybercrime investigations. Employing a comparative legal analysis approach, the study identified inconsistencies and gaps in existing regulations, particularly concerning the admissibility of digital evidence in court. The findings recommended legislative updates to enhance the reliability and admissibility of digital evidence, thereby improving the efficiency of cybercrime investigations.
4. **Zouatat & Boukais (2023):** This paper elucidated the concept of digital forensics and its role in criminal evidence. It pointed out that Algerian law lacks detailed regulations on digital forensics, highlighting significant gaps in criminal evidence practices. The study called for legislative reforms to address these gaps and enhance the use of digital forensic evidence in criminal investigations within the Algerian legal framework
5. **Brown, R., & Johnson, L. (2022):** This review explored recent advancements in digital forensic techniques and their application in criminal investigations. Conducting a systematic literature review, the researchers highlighted innovations such as block chain technology and artificial intelligence in improving forensic data analysis and evidence integrity. The study underscored the transformative impact of these technologies on enhancing investigative capabilities and ensuring justice in criminal proceedings

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7. Brown, & Johnson, (2022): This review explored recent advancements in digital forensic techniques and their application in criminal investigations. Conducting a systematic literature review, the researchers highlighted innovations such as blockchain technology and artificial intelligence in improving forensic data analysis and evidence integrity. The study underscored the transformative impact of these technologies on enhancing investigative capabilities and ensuring justice in criminal proceedings.
8. **Al-Sabaai et al. (2021)** The study proposed a mechanism for digital evidence exchange and preservation in cloud computing environments in Syria. It employed an experimental method to test the proposed mechanisms and used analytical tools to apply the SHA-2 hashing process to digital evidence, followed by encryption using Elliptic Curve Cryptography algorithms. The sample comprised digital evidence that digital investigators could rely on as digital criminal evidence in information crime cases, ensuring evidence integrity and minimizing user and cloud service provider privacy intrusions. Results indicated the proposed model's effectiveness in overcoming the single-source reliance issue in evidence formation, ensuring evidence integrity, reducing user and cloud service provider privacy intrusions.
9. **Fakihah (2021)** addressed the general rules of criminal evidence, defining criminal evidence, its purpose, the concept of criminal proof, the nature of crimes proven by modern evidence in Algerian legislation and other legislations. The study discussed the legitimacy of these methods in Algerian law and comparative legislation (comparative legislation), focusing on how they were exploited and whether this was done legally or illegally. The study concluded that proving and revealing the truth are among the most important issues of interest to judges, emphasizing the need to establish sufficient evidence of committing crimes and basing it on their perpetrator, as evidence without evidence is considered invalid.

2-3-Comparison of the Current Study with Previous Studies

2-3-1-Similarities and Differences between the Current Study and Previous Studies.

2-3-1-1-Similarities:

- **Topic:** All studies focus on the role of digital evidence in criminal investigations.
- **Methodology:** Use of electronic databases and document analysis as primary tools for data collection and analysis.
- **Objectives:** The studies aim to improve technical capabilities and develop analytical tools to combat cybercrime and protect biodiversity.

2-3-1-2-Differences:

- **Scope of Study:** The current study combines cybercrime and biodiversity protection in Yemen, while previous studies focus primarily on cybercrime in different geographical areas.
- **Tools:** The current study uses specialized analytical software to analyze extracted data, while previous studies may have focused on specific tools or aspects of digital evidence.

- **Sample:** The current study relies on a range of reference documents, electronic publications, and previous studies to ensure data comprehensiveness, while previous studies may have relied on different samples such as social media and qualitative interviews.

2-3-2-Key Benefits of Previous Studies

- **Tool Analysis:** Previous studies such as Shahraki et al. (2013) and Wahab et al. (2014) provide comprehensive analyses of digital tools used in criminal investigations, providing a basis for improving and selecting the most appropriate tools in the current study.
- **Challenges and Opportunities:** Studies such as Kim & Lee (2024) and Khan et al. (2022) highlight technical and institutional challenges in criminal investigations, which can help develop strategies to overcome these challenges in Yemen.
- **Legislation and Laws:** Studies such as Mouadine (2023) and Jarar (2022) provide legal analyses that can help understand the legal gaps in the use of digital evidence and make recommendations for developing relevant legislation in Yemen.

2-3-3-What Distinguishes the Current Study from Previous Studies

- **Dual Focus:** The current study is distinguished by its focus on the role of digital evidence in both criminal investigations and biodiversity protection, broadening the scope of research and enhancing comprehensiveness.
- **Integrated Methodology:** The current study employs an integrated methodology that includes document and electronic data analysis, as well as advanced analytical software, enhancing the accuracy and comprehensiveness of the results.
- **Geographical Focus:** The study focuses on Yemen, allowing for a deeper understanding of the specific challenges and opportunities in this complex geographical and political context.

3-Theoretical framework.

3-1-Objectives of the digital forensics:

Researchers agree that there are numerous benefits of digital forensics, including those mentioned by (Smith, 2022; Brown, 2021; Johnson, 2023). These benefits are summarized as follows:

1. Identifying the source of cyber-attacks: Determine the source of the attack, the type of damage to the IT system, and information about the attacker.
2. Analyzing the attack period: Identify the period during which the cyber-attack occurred, the type and their roles.
3. Extracting information from log files: Expertise is essential to extract the required information from various log files from different digital devices.
4. Collecting evidence from digital sources: During the investigation process, different types of evidence are collected from various digital sources in the network environment.
5. Managing digital artifact information: Artifacts contain information about activities performed on a system, essential for digital forensics investigations.

6. Digital evidence in crimes: Audio and video evidence found at a crime scene, with the victim, or the accused are critical in civil, criminal, and ethical disputes.
7. Principles of audio and video forensics: Audio and video forensics include three basic principles: obtaining, processing, and interpreting recordings admissible in court.

3-2-The task of digital forensics:

Researchers agree that there are numerous benefits of digital forensics, including those mentioned by (Smith, 2022; Brown, 2021; Johnson, 2023). These benefits are summarized as follows:

1. **Identification**: The first process involves identifying what evidence is found, where it was recorded, and how it was recorded. Electronic storage mediums include PCs, smartphones, and PDAs.
2. **Preservation**: Data is separated and human interaction with digital devices is prohibited to prevent evidence damage.
3. **Analysis**: The investigating agent reconstructs parts of the collected data and draws conclusions using evidence. Multiple assessment iterations may be required to sustain a particular offense theory.
4. **Documentation**: Evidence of all visible data is generated, aiding in reconstructing and reviewing the crime scene. This includes photos, drawings, and descriptions of the crime scene, its place, and time.
5. **Presentation**: The final process involves summarizing and clarifying conclusions, written in layman's terms with abstract and unique terminology referenced to detailed information.

3-3--Overview of Forensic Tools

With the growth of science and technology, forensic tools have become essential for investigators to analyze multimedia content and information accurately and productively. These tools ensure the validity of evidence presented in court (Horsman, 2018).

- **Teel Tech Canada** offers tools for video and audio forensic investigations, such as Corepro for image comparison using inverse projection, Impress for video enhancement, and Mandet for data analysis validity. These tools are available for free after logging in.
- **Cognitech** provides Photo and Video Investigators for photo and video enhancement and AutoMeasure Tool for biometric and scenic measurement. Both tools are paid, with no free trials.
- **Amped** offers Amped Five for video enhancement and Amped Authenticate for detecting image or video forgery. A trial version is available, but full access requires purchase.
- **Video Cleaner** optimizes photos and videos, detecting tampering, phishing, and fraud. It is free and easy to install.
- **Ocean Systems' detective** enhances video and image files for forensic investigations.
- **Kinesense** provides object recognition and enhancement with paid versions and free trials.
- **Vocord's Video Expert** offers video enhancement, authenticity, facial recognition, and report generation.

3-4-ENF-Criterion

The ENF-criterion is an efficient methodology proposed by Catalin Grigoras from the National Institute of Forensic Expertise, Ministry of Justice, Bucharest, Romania."ENF" stands for Electric Network Frequency.

3-4-1-Fundamentals of ENF-Criterion

The methodology is based on two principles:

1. The variation of the frequency value in the interconnected electrical network is equal at all points of the network at any given time (Grigoras, 2021).
2. Frequency changes are not repeatable over a long period and are unique (Grigoras, 2021).

3-4-2-Methodology

- Whenever digital equipment is used for audio recording, the acoustic signal and traces of the network frequency are recorded. This is typical for all mains-operated recorders. Battery-operated devices may also be exposed to electromagnetic radiation from the electrical network.
- The ENF can be analyzed, and its frequency variation over time can be determined. The recorded audio signal is band-pass filtered to isolate the 50 Hz ENF. A 120 Hz down-sampling reduces the signal's bandwidth, and a narrowband spectrogram provides the ENF pattern for comparison against a database (Kajstura et al., 2004).

3-4-3-Supporting Studies

- The methodology is based on principles presented by Grigoras and supported by subsequent research. Kajstura et al. (2004) conducted an experiment with simultaneous measurements of the ENF within a building, a town, and a country, finding identical frequencies in the measurements taken simultaneously.
- Morjaria studied the ENF-criterion applied to the validation of primarily analogue recordings. It was found that any analogue transfer of the recorded signal would be affected by ENF hum if not conducted in surroundings free of electromagnetic radiation (Morjaria, 2019).

3-4-4-Verification of ENF in DK:

ENF recordings for comparison were made in the continental part of Denmark (Løgumkloster, Jutland, 55.0567 N / 8.9552 E). The recordings are compared to reference recordings from Bucharest, Romania, provided by Catalin Grigoras. The results are shown in Figures 1-2 (Grigoras, 2021).

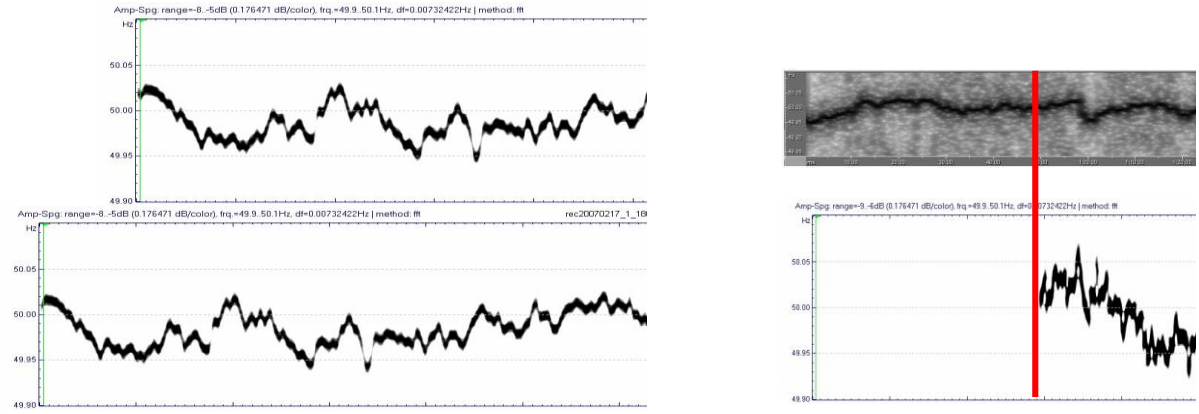

Figure 1. Upper curve: 2 hour ENF recorded in

Figure 1. Upper curve: 2-hour ENF recorded in Bucharest, Romania. Bottom curve: ENF recorded for 2 hours in Løgumkloster, the northern part of Denmark. The ENF deviation patterns—both recorded on February 17th from 1800 to 2000 GMT UTC—are identical. Vertical scale: 50 Hz ±0.1 Hz.

Figure 2. Upper curve: 2-hour ENF recorded in Bucharest, Romania. Lower curve: 2-hour ENF recorded in Løgumkloster, the continental part of Denmark. The ENF anomaly patterns—recorded on January 15th from 1000 to 1200 GMT UTC—are identical. Vertical scale: 50 Hz ±0.1 Hz

Another recording was carried out to compare the ENF in Bucharest, Romania, and in Smørum, Denmark (approximately 25 km from Copenhagen). This part of Denmark is not connected to the UTCE network, as can be clearly seen from the curves below (Morjaria, 2019).

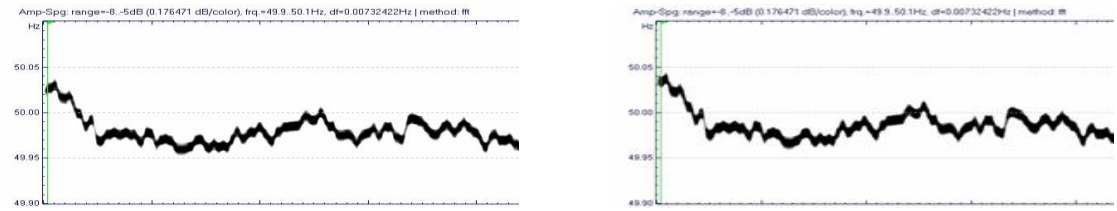

Figure 2. Upper curve: 2 hour ENF recorded in

Figure 3. Upper curve: 2-hour ENF recorded and analyzed in Bucharest, Romania. Lower curve: 1-hour ENF recorded in Smørum, Denmark. The ENF deviation patterns are both recorded on December 16th, 2006, between 1800 and 2000 GMT UTC. It can be seen that there are no similarities between these patterns.

Bucharest, Romania. Lower curve: 2 hour ENF recorded in Løgumkloster, continental part of Denmark. The ENF anomaly patterns - recorded on January 15 from 1000 to 1200 GMT UTC - are identical.

As it can be seen from these four hours of ENF recording, the patterns created by the use of spectrographic analysis yield identical curves.

As can be seen from these four hours of ENF recording, the patterns created by the use of spectrographic analysis yield identical curves (Kajstura et al., 2004).

7. General procedure audio and video forensics:

- Obtaining media information for Document file forensics:

When using media information tools, we can get results in different formats depending on the tools selected. From it, an example is obtained, such as information in XML format and information based on HTML format, and we can also obtain this media information to analyze all files, such as document file information.

Obtaining media information for audio file forensics: Using media information tools to examine audio files is one method.. The output of the media info tool is available different formats Such as XML and HTML, in addition to different formats depending on the specific audio file, which is a command

Useful for analyzing audio files, etc. During the investigation, one can view the file information, format particulars, track details, file extension details, file size, duration of the audio file, Bitrate details, performer details, file creation details and rates for different sampling and also details of compression, streaming, etc.

4-Research Methodology.

4-1-Introduction:

This research employs a descriptive survey methodology aimed at describing and documenting the role of visual and audio digital forensics in investigating cybercrimes and preserving biodiversity in the Republic of Yemen. This methodology relies on the analysis of documents, electronic publications, and previous studies.

4-2-Research Sample:

The research sample consists of a collection of reference documents, electronic publications, and previous studies related to the research topic. This sample was carefully selected to ensure comprehensiveness and coverage of all aspects related to the topic.

4-3-Research Tools:

The following tools were used for data collection and analysis:

1. **Electronic Database**: Electronic databases were utilized to access relevant publications and previous studies.
2. **Documentary Analysis**: Reference documents related to cybercrimes and biodiversity conservation were analyzed.
3. **Analytical Software**: Specialized analytical software was used to analyze the data extracted from documents and studies.

4-4-Research Implementation Steps

1. **Problem Identification and Research Objectives**: The research problem was identified, and the objectives were formulated.
2. **Data Collection**: Data were collected from electronic databases and reference documents.
3. **Data Analysis**: Data were analyzed using analytical software and documentary analysis tools.
4. **Conclusion Extraction**: Conclusions were drawn from the analyzed data and formulated into a coherent framework for future studies.

4-5-Data Analysis:

Data were analyzed using analytical software to identify patterns and trends in the documents and previous studies. Documentary analysis was applied to texts to extract information regarding the role of digital forensics in cybercrimes and biodiversity conservation.

4-6-Research Reliability and Validity

The reliability and validity of the data were ensured through:

1. **Verification of Data Sources**: Documents and studies were selected from reliable and academically recognized sources.
2. **Data Review**: The data were reviewed by the research team to ensure accuracy and reliability.

4-The results.

4-1-Types of Visual and Audio Digital Evidence for Investigating Cybercrimes and Preserving Biodiversity in Yemen

The integration of visual and audio digital evidence in the investigation of cybercrimes and the preservation of biodiversity in Yemen is a multifaceted approach that leverages modern technology to address pressing issues. Various studies and international reports have highlighted the effectiveness and necessity of using such evidence. This section discusses the types of digital evidence that can be utilized, referencing previous research and similar global experiences.

Types of Visual Digital Evidence

1. **Photographs and Images**

- **Wildlife Monitoring**: High-resolution photographs captured by drones or camera traps are pivotal in monitoring wildlife populations and identifying poaching activities. For instance, studies have shown the effectiveness of camera traps in capturing images of rare species, which can help in their conservation (WWF, 2021).
- **Crime Scene Documentation**: Photographs taken at the crime scene can provide crucial evidence in cybercrime investigations. These images can include screenshots of illicit online activities or digital devices used in the crime (Interpol, 2022).

2. **Video Footage**

- **Surveillance Cameras**: CCTV footage is invaluable in identifying and tracking the movements of individuals involved in illegal activities, such as wildlife trafficking or cybercrimes. The presence of surveillance cameras in protected areas can deter potential poachers and provide real-time monitoring (UNODC, 2020).
- **Body-Worn Cameras**: Used by law enforcement officers, these cameras capture real-time interactions during investigations, ensuring transparency and accountability. They are particularly useful in capturing the immediate response to cybercrimes and environmental violations (Interpol, 2022).

3. **Satellite Imagery**

- **Environmental Monitoring**: Satellite images help in tracking changes in land use, deforestation, and habitat destruction, which are critical for biodiversity conservation. The UN Environment Programme (UNEP, 2021) has emphasized the role of satellite imagery in detecting illegal logging and other environmental crimes.
- **Geolocation Evidence**: In cybercrime investigations, satellite imagery can be used to trace the physical locations of cybercriminals, especially when they operate in remote areas (Interpol, 2022).

Types of Audio Digital Evidence

1. **Voice Recordings**

- **Surveillance and Interception**: Recording conversations of suspects through legal wiretapping can provide direct evidence of involvement in cybercrimes or poaching activities. This method is particularly effective in disrupting organized crime networks (UNODC, 2020).
- **Wildlife Monitoring**: Audio recordings of wildlife sounds can help in identifying species presence and their behaviors. This method has been used successfully in various conservation projects to monitor bird populations and other vocal animals (WWF, 2021).

2. **Acoustic Sensors**

- **Real-Time Monitoring**: Acoustic sensors placed in forests or protected areas can detect sounds of gunshots, chainsaws, or vehicles, which are indicative of illegal activities such as poaching or logging. These sensors can trigger alerts for rapid response by authorities (UNEP, 2021).
- **Marine Conservation**: Underwater acoustic sensors are used to monitor marine biodiversity and detect illegal fishing activities. They can capture the sounds of marine animals and human activities, aiding in the enforcement of marine protected areas (WWF, 2021).

Case Studies and Global Experiences

- **Kenya's Wildlife Protection**: Kenya has successfully integrated drones equipped with cameras and acoustic sensors to monitor wildlife and detect poaching activities. This approach has significantly reduced poaching incidents in national parks (WWF, 2021).
- **Interpol's Cybercrime Investigations**: Interpol has developed a comprehensive framework for using digital evidence in cybercrime investigations. This includes guidelines for collecting, preserving, and analyzing visual and audio evidence, which have been adopted by member countries, including Yemen (Interpol, 2022).

Conclusion

The use of visual and audio digital evidence in investigating cybercrimes and preserving biodiversity in Yemen is crucial for effective law enforcement and conservation efforts. By leveraging technologies such as drones, surveillance cameras, satellite imagery, and acoustic sensors, authorities can enhance their capabilities in monitoring, detecting, and responding to illegal activities. The integration of these methods, supported by international best practices and successful case studies, provides a robust framework for addressing the dual challenges of cybercrime and biodiversity loss in Yemen.

4-2-What's the Challenges in Using Visual and Audio Digital Evidence to Investigate Cybercrimes and Preserve Biodiversity in Yemen?

To address the question, researchers have reviewed dozens of previous studies and reports. The challenges can be summarized as follows:

1. **Technological Limitations:** Infrastructure Deficiency: Yemen faces significant infrastructure challenges, including limited internet access and unreliable power supply, which hinder the deployment and maintenance of digital surveillance systems (Khan et al., 2022). Obsolete Equipment: The technological equipment available in Yemen for collecting and analyzing digital evidence is often outdated, reducing the effectiveness of investigations (Al-Kalbani et al., 2021).
2. **Legal and Regulatory Barriers:** Lack of Comprehensive Legislation: Yemen's legal framework for handling digital evidence is underdeveloped. There are no comprehensive laws that clearly define the procedures for collecting, preserving, and presenting digital evidence in court (UNODC, 2020). And Jurisdictional Issues: Cybercrimes and environmental crimes often cross national borders, creating jurisdictional challenges. Yemen's legal system lacks the necessary agreements and protocols with other nations to facilitate cooperation in such investigations (Interpol, 2022).
3. **Capacity and Expertise:** Limited Training: Law enforcement and judicial personnel in Yemen often lack the training required to handle digital evidence effectively. This includes both the technical aspects of digital forensics and the legal procedures for its admissibility in court (Al-Saadi & Al-Harazi, 2022). And Expert Shortage: There is a scarcity of qualified digital forensic experts in Yemen, making it difficult to conduct thorough investigations and analyses of digital evidence (Noman et al., 2023).
4. Data Security and Privacy Concerns: Data Breach Risks: The collection and storage of digital evidence pose significant security risks. Inadequate cybersecurity measures can lead to data breaches, compromising the integrity of the evidence (Interpol, 2022).

Privacy Issues: The use of visual and audio surveillance can infringe on individual privacy rights, leading to potential legal and ethical challenges (UNEP, 2021).

5. Environmental Challenges

Harsh Terrain and Climate: Yemen's diverse and often harsh terrain, including deserts, mountains, and coastal areas, makes the deployment of surveillance equipment challenging. Extreme weather conditions can damage equipment and disrupt monitoring efforts (WWF, 2021).

Wildlife Behavior: The effectiveness of audio and visual monitoring can be affected by the behavior of wildlife, which may avoid or damage the equipment. This requires continuous maintenance and adaptation of the technology used (WWF, 2021).

Case Studies and Global Experiences:

Kenya's Experience with Wildlife Surveillance: Kenya has implemented advanced surveillance technologies, including drones and acoustic sensors, to monitor wildlife and combat poaching. Despite facing similar challenges related to infrastructure and training, Kenya has managed to reduce poaching incidents significantly through international cooperation and investment in technology (WWF, 2021).

Interpol's Global Cybercrime Strategy: Interpol has developed a comprehensive strategy to address cybercrime, emphasizing the importance of capacity building, international cooperation, and the adoption of advanced technologies. Yemen can benefit from adopting similar strategies to enhance its capabilities in investigating cybercrimes and preserving biodiversity (Interpol, 2022).

Conclusion:

The use of visual and audio digital evidence in Yemen to investigate cybercrimes and preserve biodiversity is fraught with challenges. Addressing these challenges requires a multifaceted approach, including investing in modern technology, developing comprehensive legal frameworks, enhancing capacity building, ensuring data security, and fostering international cooperation. By learning from global best practices and adapting them to the local context, Yemen can improve its ability to tackle these pressing issues.

4-3-Best Practices for Using Visual and Audio Digital Evidence to Investigate Cybercrimes and Preserve Biodiversity in Yemen

Introduction

To address the question, researchers have reviewed numerous studies, reports, and previous research. The best practices can be summarized as follows:

1. Comprehensive Legal Framework

Develop Clear Legislation: Establish clear and comprehensive legal frameworks that define the collection, preservation, and admissibility of digital evidence. This includes specific laws for cybercrimes and environmental crimes, ensuring they are aligned with international standards (Alghamdi et al., 2022).

International Cooperation: Strengthen international cooperation through agreements and protocols to facilitate the exchange of information and collaboration in cross-border investigations (Interpol, 2022).

2. Advanced Technology Implementation

Adopt Modern Surveillance Technologies: Utilize advanced technologies such as drones, AI-powered analytics, and acoustic sensors for effective monitoring and evidence collection. These tools can enhance the detection and tracking of illegal activities and biodiversity threats (Kumar et al., 2021).

Secure Data Storage: Implement robust data security measures to protect the integrity of digital evidence. Use encryption and secure storage solutions to prevent data breaches and unauthorized access (UNODC, 2021).

3. Capacity Building and Training

Specialized Training Programs: Develop and implement specialized training programs for law enforcement, judiciary, and forensic experts. Focus on both technical skills in digital forensics and legal procedures for handling digital evidence (Al-Saadi & Al-Harazi, 2022).

Continuous Professional Development: Encourage continuous learning and professional development to keep up with the latest advancements in digital forensics and surveillance technologies (Ahmed et al., 2021).

4. Community Engagement and Awareness

Public Awareness Campaigns: Conduct public awareness campaigns to educate citizens about the importance of preserving biodiversity and reporting cybercrimes. This can help in gathering community support and cooperation in investigations (UNEP, 2021).

Collaborative Platforms: Establish platforms for collaboration between government agencies, non-governmental organizations, and local communities to share information and resources effectively (WWF, 2021).

5. Environmental and Ethical Considerations

Ethical Surveillance Practices: Ensure that surveillance activities respect privacy rights and are conducted ethically. Establish clear guidelines for the use of visual and audio monitoring to balance security needs with individual privacy (UNEP, 2021).

Environmental Impact Assessments: Conduct thorough environmental impact assessments before deploying surveillance technologies to minimize their ecological footprint and ensure they do not harm local wildlife (WWF, 2021).

Case Studies and Global Experiences

India's Use of Technology for Wildlife Conservation: India has successfully employed technologies like camera traps and acoustic sensors in wildlife sanctuaries to monitor and protect endangered species. These technologies have helped reduce poaching and gather valuable data on wildlife behavior (Kumar et al., 2021).

Interpol's Global Cybercrime Strategy: Interpol's strategy emphasizes capacity building, international collaboration, and the adoption of cutting-edge technologies. By adopting similar strategies, Yemen can enhance its ability to investigate cybercrimes and protect biodiversity effectively (Interpol, 2022).

Conclusion

Implementing best practices for using visual and audio digital evidence in Yemen to investigate cybercrimes and preserve biodiversity involves a multi-faceted approach. This includes developing a robust legal framework, adopting

advanced technologies, building capacity through training, engaging the community, and ensuring ethical practices. By learning from global experiences and adapting them to the local context, Yemen can improve its efforts in tackling these challenges.

4-4-Proposed Framework for Using Visual and Audio Digital Evidence in Investigating Cybercrimes and Preserving Biodiversity in Yemen

To address the question, researchers propose an integrated framework for using visual and audio digital evidence in investigating cybercrimes and preserving biodiversity in Yemen, leveraging the latest research and international experiences, as follows:

4-4-1-Vision: "To establish Yemen as a leader in using digital evidence to combat cybercrimes and preserve biodiversity, ensuring a secure and sustainable environment for future generations."

4-4-2-Mission: "To develop and implement robust methodologies for the collection, analysis, and utilization of visual and audio digital evidence in cybercrime investigations and biodiversity conservation efforts, through collaboration, innovation, and capacity building."

4-4-3-Values:

- Integrity: Ensuring transparency and honesty in all processes.
- Collaboration: Fostering partnerships at local, national, and international levels.
- Innovation: Utilizing the latest technologies and methodologies.
- Sustainability: Promoting practices that protect the environment and biodiversity.
- Accountability: Holding all stakeholders responsible for their actions and decisions.
- Excellence: Striving for the highest standards in digital forensics and conservation.

4-4-4-Reference Framework

Based on international standards and guidelines from organizations such as Interpol, UNODC, and WWF, as well as relevant research studies.

1. Strategic Objectives
2. Enhance Technical Capabilities
3. Strengthen Legal and Regulatory Frameworks
4. Promote Awareness and Community Engagement
5. Foster International Cooperation

4-4-5-Operational Matrix:

Strategic Goal 1: Enhance Technical Capabilities

Sub-objectives	Develop advanced digital forensics labs	Implement AI and machine learning tools
Activities and Means	Establish and equip digital forensics laboratories.	Integrate AI tools in data analysis processes.
Responsible Entity	Ministry of Local Administration, International Partners	Ministry of Local Administration, Academic Institutions
Estimated Costs (USD)	$5 million	$3 million
Time Frame	2025-2027	2026-2028

Indicators	Number of labs established, number of trained personnel	Number of AI tools implemented, effectiveness of data analysis
Risk Strategy	Regular maintenance and updates of equipment, continuous training programs.	Collaboration with tech firms for ongoing support, regular software updates.

Strategic Goal 2: Strengthen Legal and Regulatory Frameworks

Sub-objectives	**Update legislation for digital evidence**	**Establish clear protocols for evidence handling**
Activities and Means	Draft and enact laws specific to digital evidence.	Develop comprehensive guidelines for evidence collection and storage.
Responsible Entity	Ministry of Justice, Parliament	Ministry of Justice, Judiciary
Estimated Costs (USD)	$500,000	$300,000
Time Frame	2025-2026	2026-2027
Indicators	New laws enacted, number of workshops conducted	Protocols established, number of training sessions
Risk Strategy	Continuous advocacy and lobbying, engaging international legal experts.	Regular reviews and updates of protocols, feedback loops from law enforcement.

Strategic Goal 3: Promote Awareness and Community Engagement

Sub-objectives	**Launch public awareness campaigns**	**Foster community-based monitoring initiatives**
Activities and Means	Develop multimedia campaigns on cybercrime and biodiversity.	Train local communities on monitoring techniques.
Responsible Entity	Ministry of Tourism, NGOs	Ministry of Local Administration, Environmental NGOs
Estimated Costs (USD)	$1 million	$800,000
Time Frame	2025-2029	2025-2028
Indicators	Campaign reach, engagement levels	Number of trained community members, reports generated
Risk Strategy	Continuous monitoring and adaptation of campaigns, partnerships with media outlets.	Regular follow-up and support, incentivizing community participation.

Strategic Goal 4: Foster International Cooperation

Sub-objectives	**Establish international partnerships**	**Share best practices and knowledge**
Activities and Means	Sign MOUs with international forensic and conservation organizations.	Organize international workshops and training sessions.
Responsible Entity	Ministry of Foreign Affairs, International Partners	Academic Institutions, Research Centers
Estimated Costs (USD)	$700,000	$600,000
Time Frame	2025-2029	2025-2029
Indicators	Number of partnerships established, participation in events	Number of workshops held, publications produced
Risk Strategy	Continuous engagement with international bodies, regular evaluation of partnerships.	Collaborations with leading experts, continuous knowledge exchange.

This format maintains a structured approach with detailed objectives under each strategic goal, including activities, responsible entities, timelines, costs, indicators, and risk strategies.

4-5-Discussion Current Results with previous studies:

Our study on visual and audio digital forensics in Yemen focuses on utilizing forensic tools to investigate both cybercrimes and biodiversity conservation issues. The findings from the discussed studies underline the importance of rigorous forensic methodologies, specialized tools, and technological advancements in handling digital evidence across

various contexts. Integrating these insights can strengthen the applicability and effectiveness of digital forensics in complex environments like Yemen, addressing both cyber security and environmental conservation challenges.

5-Recommendations and suggestions.

5-1-Recommendations:

1. **Establish Specialized Training Programs: Develop specialized training programs in visual and audio digital forensics for law enforcement and forensic professionals in Yemen and other Arab countries. Implement these programs in collaboration with universities and international forensic agencies.**
2. Enhance Technological Infrastructure: Invest in upgrading technological infrastructure for digital forensics laboratories, focusing on advanced tools for audio and video analysis. Collaborate with technology firms to develop localized solutions that cater to regional needs.
3. Form Interdisciplinary Task Forces: Establish interdisciplinary task forces comprising biologists, environmental scientists, and digital forensics experts to investigate complex cases involving biodiversity crimes. Ensure collaboration between environmental protection agencies and law enforcement.
4. Promote International Cooperation: Foster partnerships with international organizations and neighboring countries to share expertise and resources in combating cybercrimes related to biodiversity conservation. Facilitate joint investigations and information exchange.
5. Create Public Awareness Campaigns: Launch public awareness campaigns about the role of digital forensics in protecting biodiversity and combating cybercrimes. Educate communities, policymakers, and businesses about the importance of preserving natural resources and preventing digital crimes.

5-2-Future Study Suggestions:

A. Investigate the integration of block chain technology in digital forensics to enhance data integrity and traceability in biodiversity conservation efforts and cybercrime investigations.

B. Explore the application of artificial intelligence (AI) and machine learning algorithms in automating the analysis of visual and audio evidence to expedite forensic investigations in diverse ecological and cyber contexts.

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