



# **COMBINING DIGITAL FORENSICS AND BEHAVIORAL ANALYTICS TO STOP CYBERCRIMINALS: A DIGITAL FORENSIC PROFILING FRAMEWORK**

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**Abstract:** This paper proposes a digital forensic profiling framework that combines digital forensics and behavioral analytics to identify and stop cybercriminals. With the increased use of digital services, cybercrime has become a significant challenge for law enforcement agencies. The study shows the need to include behavioral evidence analysis as part of the digital forensics examination to address criminal patterns in cybercrime, particularly social engineering attacks. The literature review covers cyber security challenges, digital transformation, and the adoption of digital forensics as a solution to emergent cybersecurity challenges. The paper explores the relationship between criminal profiling, behavioral analytics, and digital forensics. The research methodology includes a qualitative content analysis of academic peer-reviewed scholarly academic journals, theses, and doctoral dissertations authored or presented between 2001 and 2021 that addressed digital forensics and behavioral analytics. The study recommends the use of standardized investigation methods and the inclusion of human factors in digital forensic frameworks. In conclusion, the paper calls for the need for a more generalizable digital forensic method to address cyber security challenges in digitally dynamic organizations.

**Keywords:** digital forensics, behavioral analytics, cybercrime, criminal profiling, evidence analysis, cyber security.

## **1. INTRODUCTION**

Data and information are among the most vital assets in any modern organization. Human, organizational, and technological aspects play a central consolidative role in information security and digital forensics in safeguarding these important assets. However, the security and integrity of such assets is increasingly threatened by malicious cyberspace users. Even with the adoption of proactive stop-gap measures, the rise in cybercrime has led to significant losses. An assessment of the 2020 Information Systems Audit and Control Association's (ISACA) annual report on the state of cyber security provided an insight into the increasing threat of cybercrime [1]. This report used insight from 2,000 information security experts across seventeen industries, to investigate the cybersecurity landscape. The report concluded that cyberattacks have been on the increase year over year since 2010 [1]. The report also revealed that the threat actors were divided as follows,



# **American International Journal of Computer Science and Information Technology (AIJCSIT)**

Volume.1, Number 1; March-2023;

Published By: Zendo Academic Publishing

<https://zapjournals.com/Journals/index.php/aijcsit>

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external cybercriminals (22%), malicious insiders at (11%), non-malicious insiders at (10 %) followed by state actors (9 %) then hacktivists at 8%. In the report, the most prevalent attack techniques used were social engineering which stood at 15%, followed by advanced persistent threat at 10%, and subsequently ransomware and unpatched systems at 9% each [1].

The Finance Online Research Center 2022/2023, which reported on 10 cyber security predictions, recognized that cybercrime was the fastest-growing crime globally. Notably, the financial losses suffered by organizations outnumber overall income in the international illegal drug trade [2]. Unfortunately, these attacks also target small enterprises that lack sufficient cyber security capacity to protect themselves. This report also identified the common cyber-attack method facing companies based in the United States. The threats included phishing at 38%, network

DOI: 10.5121/ijcsit.2023.15106

intrusion at 32%, inadvertent disclosure at 12%, theft and loss of devices and records at 8%, and system misconfiguration at 5% [2].

Based on the two reports, it is apparent that social engineering attacks based on phishing are a growing threat. The threat involves system intruders targeting employees who connect to their employer's network remotely from home or away from the office. The hackers use manipulation that exploits human error to gain private information, access, or valuables with the intent to use such information against the employee. Such attacks have resulted in huge losses which have shifted focus towards identifying criminal behaviors instead of simply focusing on physical and device security alone.

The study of behavioral tendencies is informed by the fact that most cybercriminal activities are grounded on certain patterns, especially social engineering. This paper proposes the combined use of digital forensics and behavioral analytics to create a digital forensic profiling framework for analyzing evidence. The framework should provide a definitive criminal profile to identify cybercriminals and stop them before they commit further crimes.

## **1.1. Problem Statement**

Specialists in digital forensics have been experiencing unforeseen difficulties because cybercriminals are increasingly using innovative and sophisticated techniques to commit crimes. In many cases, such as social engineering attacks, the evidence is often not enough to minimize the list of possible suspects. These challenges can be solved with a combination of digital forensic processes that include focusing on the criminal's behavior in addition to the conventional analysis process. However, even the addition of human behavior as a factor requires a proper framework that can be used uniformly and effectively.

## **1.2. Background to the Study**

The increased use of digital services across almost all social, economic, and regulatory speeches has made computers a predominant part of human life. However, the same increased use of digital devices has resulted



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in increased cases of cybercrime activities. As a result, law enforcement and judicial authorities are facing increasing pressure to adopt proactive means of including digital ways of collecting and analyzing evidence in both the physical and cyber spheres. This study acknowledges the shortcomings of past digital forensic and evidence collection mechanisms. Most of the digital frameworks identified so far failed to acknowledge the strengths of previous frameworks. As such, it has been hard to have a unified digital forensic methodology that would draw consensus among architects of previous frameworks. This assessment sought to collate a comprehensive review of digital forensic framework proposals that are available to the public. It also sought to delineate between those frameworks that have a behavioral evidence analysis aspect and those that lack the same.

## **1.3. Study Objectives**

This study sought to: (i) explore the application of behavioral analytics in digital forensics; (ii) explore the existing behavioral evidence analysis framework to establish their strengths and weaknesses.

## **2. LITERATURE REVIEW**

This section provides an assessment of the literature relating to the primary objectives outlined in the introduction section of this research paper. The literature review also covers the concepts of behavioral analytics, cyber security challenges, digital transformation, and the adoption of digital forensics as a solution to emergent cybersecurity challenges. Finally, the assessed literature also addresses the use of digital forensic frameworks for investigations and as a barrier to cybercrime.

### **2.1. Cybersecurity Challenges in Digitally Dynamic Organizations**

Cybersecurity is a growing global concern for personal digital device users, businesses, and state agencies. The cybercrime space has been evolving fast, with the adoption of new digital technologies and practices such as the internet of things and remote work. In a world where most aspects of life are becoming digitalized, one of the greatest difficulties in the field of cybersecurity is guaranteeing the safety of data [3]. However, the aspect of human beings as Information Technology system operators has remained constant. Social engineering, which provides an actual link between criminals and their targets, has also become a prevalent problem due to the operational position held by legitimate system users. Spear phishing and spoofing often serve as the initial vector for intrusive attacks against organizations and individual victims of cybercrime.

### **2.2. Digital Forensics**

In most cases, cybercrime scenes tend to be online or have a digital dimension that requires expert analysis leading to the need for digital forensic analysis. Notably, digital forensics assists authorities in forensically and methodically determining when an event happened, when it occurred, where it transpired, why it ended up happening, and, ideally, who is responsible. Such data is required to certify that the evidence discovered is adequate to indict a person for the unlawful offense perpetrated [4]. All this information is needed to guarantee that there is enough evidence to prosecute and convict a cybercriminal. Digital forensics (DF) is a sub-field of



forensic science that focuses on the study of the digital environment. DF, like any other forensic investigation, employs scientific procedures to discover evidence. The primary purpose of DF is to ensure evidence gathered in the investigation is credible and admissible before the court of law[5].

### **2.3. Behavioral Analytics**

Behavioral analytics is a concept that employs principles such as motive, mode of operation, signature behavioral patterns, offender schemas, and victim personas to better probe criminal activity [6]. It is worth stating that hard data is the bedrock of behavioral analytics. Behavioral analytics is a subfield of data analytics concerned with gaining insight into the activities of individuals [6]. Initially oriented towards violent offenders, behavioral analytics has been expanded to cover other aspects of criminology. This field utilizes vast amounts of raw data collected from various platforms and devices including social media, gaming apps, retail websites, and apps [7]. The information is gathered, processed, and then utilized as the basis for making choices, such as how to predict future criminal trends. Behavioral analytics may support a variety of assumptions. The assumptions make iterative testing and assessment a key component of this field.

### **2.4. The Relationship between Digital Forensics, Criminal Profiling, and Behavioral Analytics**

In the field of digital forensics, behavioral analytics involves the logical investigation method that looks at evidentiary material from a particular event and focuses on specific personality and behavioral patterns to figure out what the probable offender is like. Notably, Behavioral evidence analytics (BEA) practice includes four sets of assessments (Figure 1) including equivocal forensic analysis [8], forensic victimology [9], identification of crime scene characteristics [10], and determination of criminal tendencies [8], [11]. These four categories are used to arrive at a comprehensive methodology for investigating crime.

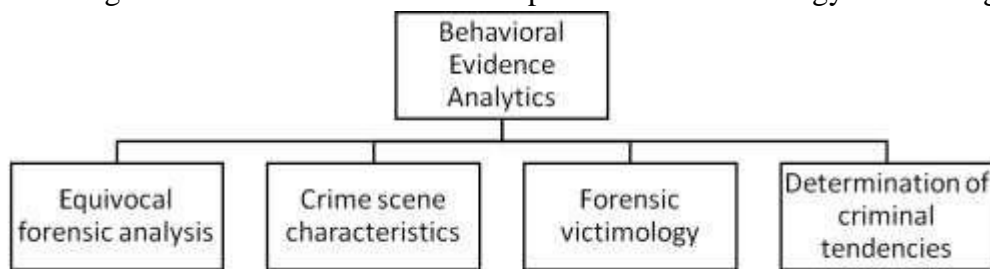


Figure 1. Digital forensic assessment areas

Criminal profiling involves figuring out what kind of an individual or a group of suspects are by using the actions they take while committing a crime(s) [11]. Cybercriminals often have unique goals and motivating factors that form a pattern just like criminals in the physical world. Profiling in digital forensics can be used to identify such patterns, and more investigators are choosing to adopt the same [12]. Furthermore, the overall set of crime investigation processes is often similar to those used in a traditional crime investigation, such as what drove the criminal or why they chose an individual target.



### **3. DIGITAL FRAMEWORKS**

One of the earliest digital forensics frameworks was the US Department of Justice's Digital Forensics Investigation Process Model [13]. This model was a four-stage model consisting of securing and analyzing the incident, recording the incident, collecting evidence, as well as packing, transporting, and organizing digital evidence. A 2002 article introduced a new framework to standardize the DF process, but the seven processes proved too general for proper use [14]. An Integrated Digital Investigation Process consisting of (1) preparation, (2) distribution, (3) physical crime scene examination, (4) digital crime event investigation, and (5) appraisal; was introduced by [15].

Subsequently, a two-tiered model was created to cover primary crime and physical crime scenes distinctly in 2004 [16]. A six-step framework that was aimed at incorporating specificity and practicality in the investigative process followed the 2004 model [17]. The six-step model was woven around preparation, incident response, data collection, analysis, presentation of findings, and incident closure. A minor adjustment that sought to address the legal challenge in the digital evidence analysis process by adding attribution and reconstruction was incorporated into a 2010 model [18]. A 2010 research article proposed the systematic digital forensic investigation model that included eleven phases. The eleven phases included scene preparation, scene lockdown, survey and identification, scene recording, communication blocking, evidence collecting, preservation, inspection, analysis, presentation, and outcome [19].

A 12-step harmonized model that covered both traditional and digital forensic concepts was proposed in 2012 [20]. The steps within this assessment included the identification of incidents, initial response, planning, preparedness, documenting of the event location, and identification of possible evidence. It also involved the gathering of prospective evidence, conveyance of potential evidence, storage of potential evidence, examination of potential evidence, presenting, and result cataloging. While noting that previous frameworks failed to incorporate the practical needs of digital forensic investigators, several researchers proposed the use of an eight-step process that incorporated preparation, identification, incident response, evidence gathering, evaluation, analysis, presentation of information, and closure [21].

All of the frameworks above lacked the inclusion of behavioral aspects in the forensic analysis process. A consequent analysis of previous structures developed a framework tailored toward cyberstalking cases that included aspects of behavioral evidence analysis [22]. This model was broken down into detection and complaint, examination and evaluation. A 2015 assessment provided an alternative BA-focused approach of dealing with sexual crimes that involved six steps beginning with the categorization of cases, contextual analysis, collecting of data, statistical evaluation, chronological analysis, and visualization, as well as decision-making and expert opinion [23]. A more comprehensive analysis [8] combined the concept in [22] with [23] to develop a four-step process consisting of review, recognition and gathering, examination and analysis as





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well as assessment and presentation. Table 1 below provides a tabulated breakdown of the digital forensic frameworks.

Table 1. Digital forensic framework proposals through the years.

Author(s)	Year	Constituent variables
Federal Bureau of Investigation [13]	2001	(1) Securing and analyzing the incident, (2) recording the incident, (3) collecting evidence, (4) secure packing and transporting of evidence, (5) organizing digital evidence
Reith, Carr, and Gunsch [15]	2002	(1) Preparation of evidence, (2) distribution, (3) physical crime scene examination, (4) digital crime event investigation, and (5) appraisal.
Baryamureeba and Tushabe [16]	2004	(1) Preparation, (2) incident response, (3) data collection, (4) analysis, (5) presentation of findings, (6) incident closure.
Beebe and Clark [17]	2010	(1) Crime scene preparation, (2) scene lockdown, (3) survey and identification, (4) scene recording, (5) communication blocking, (6) evidence collecting, (7) preservation, (8) inspection, (9) analysis, (10) presentation, (11) outcome.
Valjarevic and Venter [20]	2012	(1) Identification of incidents, (2) initial response, (3) planning, (4) preparedness, (5) documenting of the event location, (6) identification of possible evidence (7) gathering of prospective evidence, (8) conveyance of potential evidence, (9) storage of potential evidence, (10) examination of potential evidence, (11) presenting, (12) result cataloguing
Silde and Angelopoulou [21]	2014	(1) Detection and complaint, (2) examination and evaluation
Montasari, Peltola and Evans [22]	2015	(1) Preparation, (2) identification, (3) incident response, (4) evidence gathering, (5) evaluation, (6) analysis, (7) presentation of information, (8) closure



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Rogers and Seigfried [23]	2016	(1) Categorization of cases, (2) contextual analysis, (3) collecting of data, (4) statistical evaluation, (4) chronological analysis, (5) visualization
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## 4. RESEARCH METHODOLOGY

This qualitative content analysis study looked at academic peer-reviewed scholarly academic journals, theses, and doctoral dissertations authored or presented between 2001 and 2021 that addressed digital forensics and behavioral analytics. Content analysis has been defined as the impartial, methodical, qualitative research of a document's features [24]. The sources were TW Universal academic database as well as ProQuest Dissertation. TW Universal and ProQuest were used because they provided access to comprehensive academic directories with a large range of full-text academic journals, dissertations, and theses.

## 5. FINDINGS

Up until 2014, none of the existing frameworks were tested in practical situations. The theories and methods that went into making them were not tested in the real world. Models that outlined the steps used did so with made-up examples and scant information that lacked clarity over how the steps were used. Also, the models that explained these different phases concentrated on what needed to be done during each phase, but they did not give enough information about how to carry out the inquiry. Until 2014, the frameworks didn't take into consideration the individuals engaged in the DF investigation. They also did not consider the behavioral, motivational, or social aspects of criminal behavior that could help find possible evidence during investigations. Critically, each framework is built upon the failures of the preceding frameworks. Based on the assessment of the various frameworks it was clear that the use of BA in digital crimes may help the investigative process in a variety of ways. Specifically, the use of BA offers a methodical strategy for directing investigators to possible sources of forensic evidence in the analyzed devices. It also gives information on individual offender traits and behaviors, which may help with risk assessment. A key benefit of BA inclusion into the analysis process was the adoption of methodologies that could and were applied in the field. Additionally, the frameworks covered from 2014 onwards had a sense of standardization and were much simpler in comparison to those used before them. The disadvantage of behavioral digital forensic frameworks is their specificity to crime categories. For instance, while [23] and [8] dealt with sexual crimes, the framework in [22] was constrained to cyberstalking.

## 6. RECOMMENDATION

This research has provided a review of the major digital frameworks provided thus far. The paper has also shown how the inclusion of behavioral evidence analysis has revolutionized the composition of digital forensic frameworks. However, most of the frameworks have remained untested beyond the proposal. Future



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researchers on the subject should focus on proving the efficacy of some of the frameworks, even if such an assessment will begin in the post-behavioral analysis age.

## 7. CONCLUSION

The growing complexity and power of digital technologies have made it vital to keep an eye on how cyber techniques are used to deter exploitation. The methodologies used to deal with online crimes must also change to keep up with the adoption of new digital skills. Because of this, digital forensics has needed improvement. When Behavioral Evidence Analysis is added to the digital forensic processes, it makes it easier to solve digitally facilitated crimes and provide future preventive as well as detective mechanisms in behavioral evidence. The suggested BEA model, on the other hand, aims to create a standardized approach that can be employed in all criminal cases. This paper details how well BEA works and spells out how to use it in the digital forensic process. By tracing the development of current digital investigation frameworks, this paper establishes the importance of behavioral analytics in the digital investigation process.

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Published By: Zendo Academic Publishing

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