Journal of Applied Engineering, Technology and Management (JAETM)

Forensic analysis of Scientific Linux image using commercial and opensource forensic tools

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Published: June 2024

DOI: https://doi.org/10.54417/jaetm.v4i1.133

Abstract

Depending on their needs and personal preferences, people choose to use different operating systems (OS) such as Windows, Linux, and Mac. The scientific Linux Operating System (SLOS) is designed to provide a stable, secure, and high-performance computing environment for scientific research and education in a steady, scalable, and extensible manner. When criminal activities are committed by suspects involving computers and the internet, it calls for digital forensics which involves the use of scientific procedures and tools to carry out the forensic investigation and analysis of digital evidence for legal and investigative purposes. Forensic investigators use commercial and opensource tools for analysis and gathering inculpatory and exculpatory pieces of evidence. This paper presents a comparative analysis of EnCase, FTK, Autopsy, bulk-extractor, and Scalpel for analyzing the Scientific Linux image. The test scenarios were designed to find out if the selected forensic tools can be appropriately used for investigating crimes committed using the SLOS. The test scenarios include extraction and analysis of operating system details, user accounts, web browsing history, and the recovery of deleted and shredded files and this paper compares and evaluates the capability of the tools in retrieving the evidence designed in the scenarios. This systematic comparison and evaluation results would assist digital forensics practitioners, researchers, and law enforcement agencies in making informed decisions regarding the selection of tools for Scientific Linux image forensics.

Keywords— Digital forensics, evidence gathering, forensic analysis, forensic tools, Scientific Linux

1 Introduction

Digital forensics entails the collection, preservation, analysis, and presentation of digital evidence from various sources, such as computers, mobile devices, networks, and cloud services, and computer forensics involves extracting information from various sources like software, databases, the

internet, and emails [1]. It plays a vital role in the investigation and prosecution of cybercrimes, such as hacking, fraud, identity theft, cyberterrorism, and child pornography. In addition, digital forensics also supports other domains, such as civil litigation, corporate security, and incident response. Investigations uncovering network details are beneficial, as they facilitate communication and information sharing between computers [2].

The rise of virtualization, distributed, and cloud computing poses new challenges in forensic science [3][4]. One of the challenges of digital forensics is the diversity and complexity of operating systems (OS) that the suspects and the victims of cybercrimes use. An OS is the software that manages a computer's hardware and software resources and provides the interface for the user to interact with the computer. There are different types of operating systems which include Windows, Linux, and Mac. OS has different features, functions, architectures, file systems, and security mechanisms.

Today's technology allows for evidence gathering from diverse hardware, including memory cards, smart cards, dongles, cameras, biometric scanners, routers, pagers, printers, answering machines, and GPS systems. This analysis concentrates on key features essential for the forensic examination of evidence. Areas not covered in this study include forensic readiness planning, evidence acquisition, protocols, protecting evidence integrity, and legal considerations in forensic investigations. Various digital data formats and types have led to the development of multiple analysis types, as classified by the Digital Forensics Research Workshop (DFRWS). [5] details the procedure and progression of digital forensic investigations.

Forensic investigators' selection of digital forensic tools depends on each case's unique characteristics and requirements [6][7]. Ideal forensic tools should support multiple platforms and operating systems, analyze different file systems, incorporate scripting for function automation, feature significant automated capabilities, and offer robust product support. Tools that provide comprehensive features and multi-platform support are typically more advantageous. A thorough evaluation of each tool's features aids investigators in choosing the most suitable tool, thus optimizing investigation time and effort. This allows investigators to concentrate on other investigation facets like case preparation, evidence collection, custody chain maintenance, and report writing.

OS Forensics (tool) identifies suspect files and activities through hash matching and drives signature comparisons, focusing on emails, memory, and binary data [8]. This tool facilitates rapid forensic evidence extraction and efficient data management, supporting various Windows versions and server platforms. OS Forensics, available in both trial and paid versions, boasts features like Misnamed file searching, Drive signature comparison, and discovering hidden disk areas.

The file system's significance in computing lies in organizing files indicating data locations, beginnings, and endings. Each file system, unique in size, follows a structure recognizable by any supporting computer [9]. File systems vary in structure, speed, flexibility, security, and size, with some tailored for specific applications, like ISO 9660 for optical discs [10].

Various storage devices support different file systems, for example, SSDs [11]. Examples include RAM as a temporary file system and network-accessible systems like NFS and SMB. File system analysis involves processing data within a partition or disk, including file listing, recovery of deleted content, and viewing sector content. [12] conducted a comprehensive review of the current state of research on dark web forensics, focusing on the methods, tools, and challenges associated with this field, emphasizing the importance of continuous improvement in darknet forensics technology for combating darknet crimes.

[13] explored Linux system architecture and forensic tools in "Linux Forensic Triage." This study delved into Linux system layers (Hardware, Kernel, Shell, Application) and various tools for Linux forensics, highlighting the value of open-source tools and the role of auditing, logging, and file system journaling. [14] examined open-source and closed-source tools for forensic analysis in "A Study of Linux Forensics." The study emphasized the effectiveness of open-source tools in Linux forensics, focusing on auditing, logging, and file system journaling as primary information sources. [15] in the State-of-the-art Tools and Techniques for Remote Digital Forensic Investigations", compared

advanced software and hardware tools for remote forensic acquisition, evaluating them based on outputs from memory, timeline, and live forensic imaging to determine the most effective techniques for remote investigations under various conditions.

Scientific Linux (SL) is a Linux distribution based on Red Hat Enterprise Linux (RHEL). Fermilab, CERN, and other scientific and academic institutions developed it. It is designed to provide a stable, secure, and high-performance computing environment for scientific research and education. SL is widely used in various fields, such as physics, astronomy, biology, and engineering. SL is also a potential platform for cybercriminals who seek to exploit its features and avoid detection. For example, SL offers a high degree of customization, allowing users to modify the OS according to their needs and preferences. SL also supports encryption and anonymization tools, such as LUKS, GPG, and Tor, which can protect the user's data and identity from unauthorized access and surveillance.

Operating System Forensics involves gleaning crucial information from a computer or mobile device's operating system [16] to secure empirical evidence against suspects. An OS, the first application to run at system startup, is analyzed for configuration files and output data to deduce possible events. [17] conducted a forensic analysis of the unencrypted layer in the Tor network to investigate the potential for de-anonymizing Tor users and determining their online activities. They focused on capturing and analyzing network traffic from the Tor Browser running in the Tails operating system.

Forensic tools must be able to handle each OS's specific characteristics and requirements and extract and analyze the relevant data and artifacts. Therefore, evaluating the performance and suitability of forensic tools for investigating digital crimes committed using the Scientific Linux operating system is important. However, there is a lack of research and literature on this topic. Most existing studies focus on comparing forensic tools for Windows, Mac OS, or Android OS, which are more popular and widely used than SL. Moreover, there is a debate on the advantages and disadvantages of commercial and open-source forensic tools, which have different features, costs, and licenses.

This paper aims to fill this gap by conducting a comparative analysis of five forensic tools, namely EnCase, FTK, Autopsy, bulk-extractor, and Scalpel for investigating digital crimes committed using SL. EnCase and FTK are commercial forensic tools widely used by law enforcement and the private sector. Autopsy, bulk-extractor, and Scalpel are open-source forensic tools that are freely available and can be modified by the user. The paper presents four test scenarios that cover the extraction and analysis of operating system details, user accounts, web browsing history, and deleted files. The paper compares and evaluates the tools' capability to retrieve artifacts. The paper also discusses the advantages and disadvantages of commercial and open-source forensic tools and provides recommendations for forensic practitioners and researchers.

2 Methods and Materials

2.1 Experimental design

As a part of the scenario preparation, the following environmental scenario was arranged to simulate how the suspects would use a device for committing the crime. The Scientific Linux 7.5 release was installed on the Oracle VM VirtualBox Manager (Version 5.2.16) and allocated the hard drive size of 8GB, 2048MB of RAM, and the system's timezone was set to Asia/Kolkata. The password for the root user was set to "abcde123" and another user with the name "zala" was created and assigned the password "abcde123". The Scientific Linux 7.5 was run and accessed the websites using the default browser of the operating system, that is "Konqueror", and in addition, files were also downloaded. While browsing the IP address was noted to be 10.0.2.15 (VirtualBox NAT). The sites visited are www.gfsu.edu.in and www.kuenselonline.com, downloaded file (QuickTimeInstaller.exe) from "ftp://jnec.edu.bt". To /mnt directory "FindMyDevice.pdf", "FindMyDevice.docx", "WHOIS.pdf",

and "WHOIS.docx" were copied from the USB drive. The file FindMyDevice.pdf was removed using the remove (rm) command from the directory and the file WHOIS.docx was overwritten and removed securely using the command "shred -zvu 5 WHOIS.docx" command from the terminal.

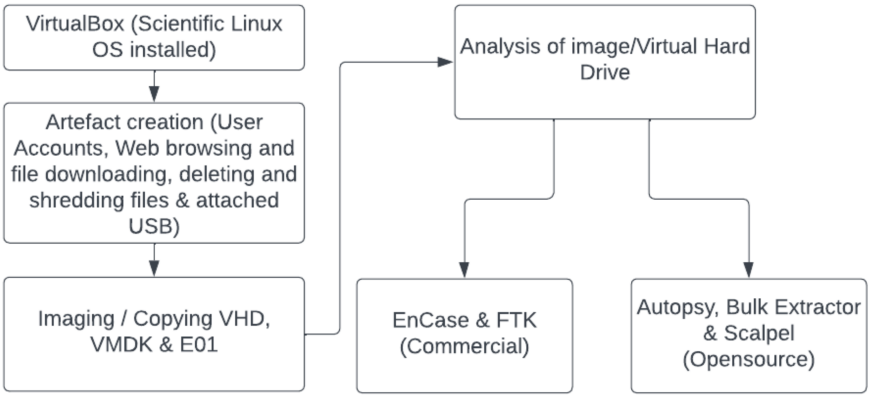


Figure 1: Artefact creation and analysis process

2.2 Software used for image analysis

The forensic artifacts are subdivided into sections based on the different Forensic Tools used for analysing the evidence file and the expected type of evidence to be recovered from the evidence file after the analysis. The Forensic tools used for the analysis of the evidence file are EnCase, FTK, Autopsy, Bulk_extractor, and Scalpel.

3 Results and Discussion

The image or virtual hard drives copied from the VirtualBox were loaded into EnCase, FTK, Autopsy, Bulk Extractor, and Scalpel for analysis and retrieving the evidential artefacts. The results are presented in the following sections.

3.1 Analysis using EnCase

The EnCase after loading and analysing the image of the Scientific Linux 7.5 (Operating System), failed to show, the operating system version, operating system installation date, user accounts details, browsing and download history, file transfer history, deleted and shredded files (Recover), and the attached USB devices' details. Figure 2 shows the result of searching www.kuenselonline.com as the keyword but failed.

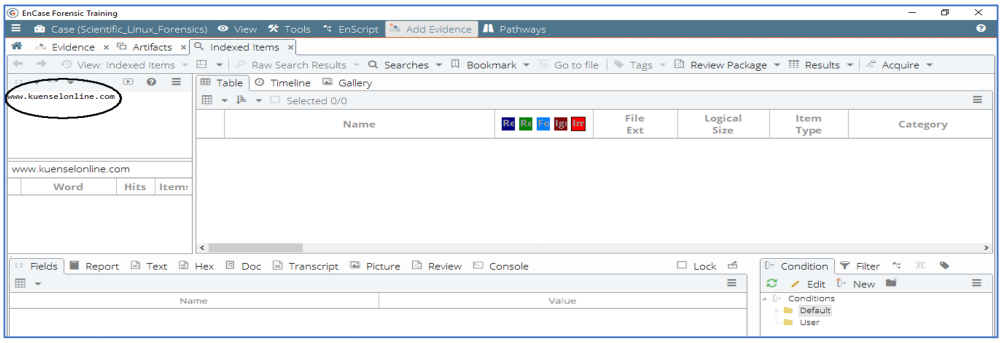


Figure 2: Searching the browsed website (www.kuenselonline.com) in the indexed items

3.2 Analysis using FTK

To recover the artifacts, FTK 6.2.1.10 was installed and the evidence file in the vmdk format was loaded. The FTK was able to analyse the evidence file but artifacts had to be manually searched using the index search feature. FTK after loading and analysing the image of the Scientific Linux 7.5 (Operating System), could not populate results and hence the index search feature was used to fetch the probable evidence. The following details were found using the keyword search as indicated by Figure 3, Figure 4Figure 5Figure 6Figure 7.

3.2.1 Operating System Version

The following figure shows the Operating System as Scientific Linux and version 7.5 (Nitrogen).

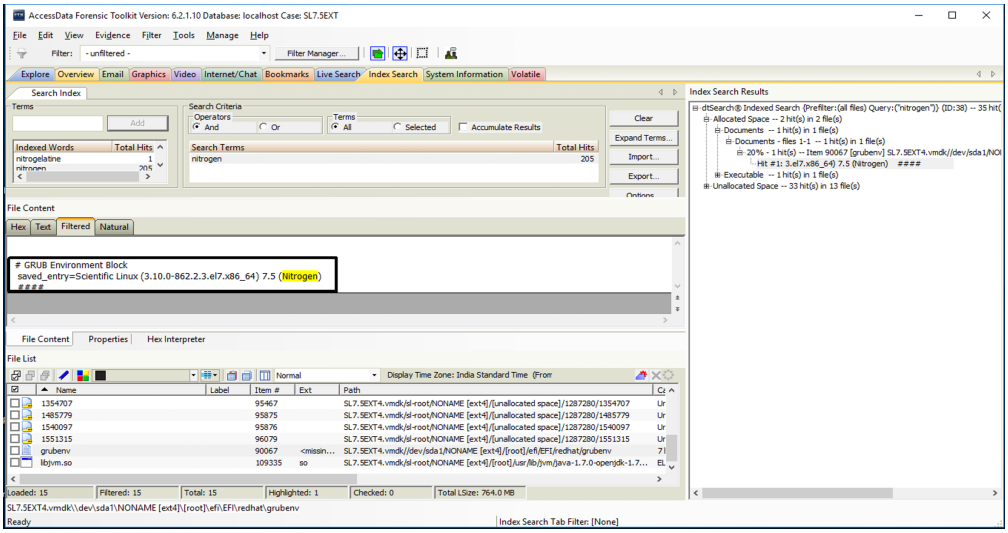


Figure 3: FTK showing OS name and version

3.2.2 Operating System Installation Date

The FTK has shown that the Operating System installation date in GMT format is Tuesday, 6th November 2018, and an approximate time also.

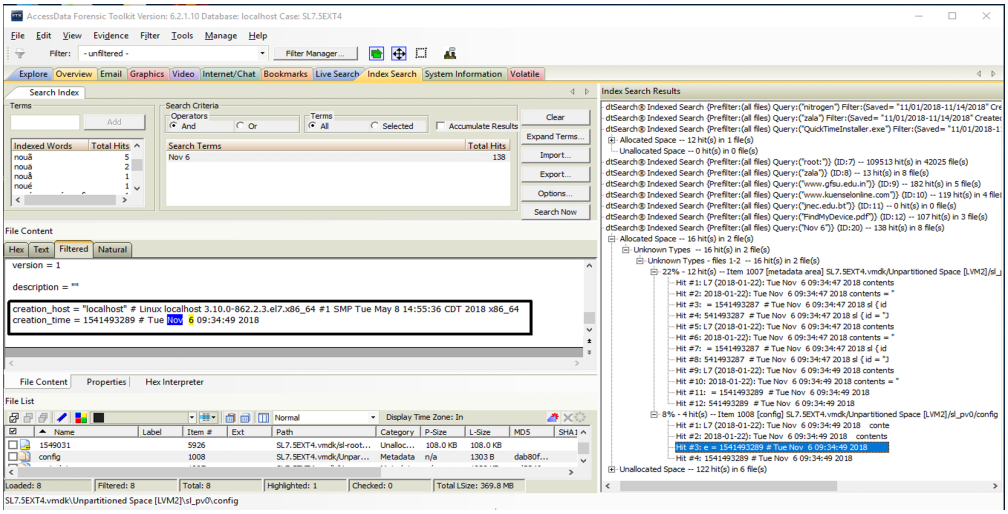


Figure 4: FTK showing OS installation date and time in GMT

3.2.3 Browsing History

The autopsy shows the websites and the FTP sites being browsed when it is being searched using the keyword feature. The websites http://www.gfsu.edu.in and http://www.kuenselonline.com, and also the FTP site ftp://jnec.edu.bt are being fetched from the browsing history as shown in the following figures respectively.

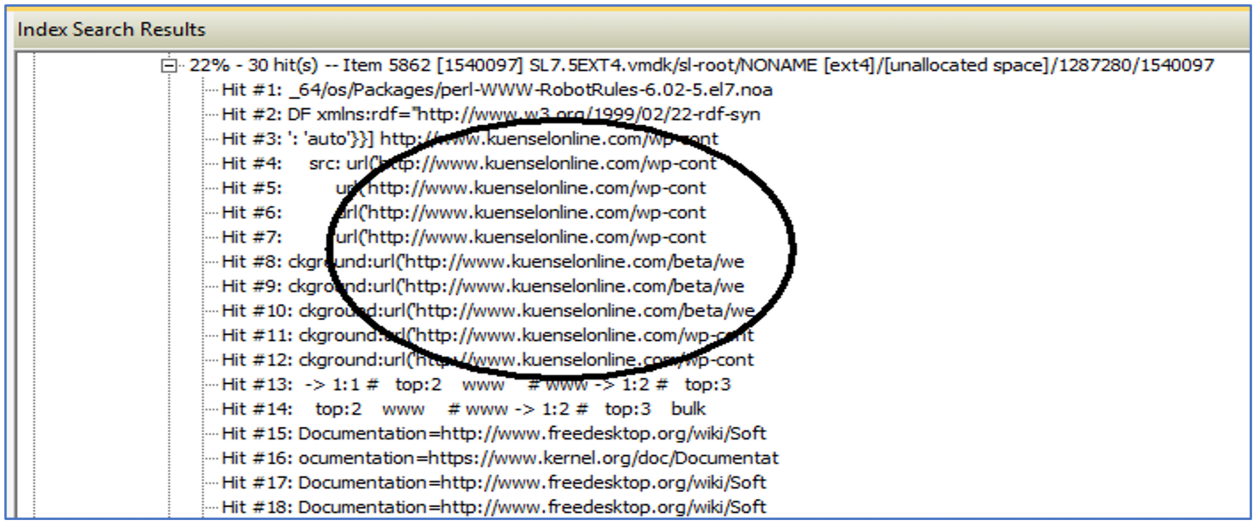


Figure 5: FTK showing www.kuenselonline.com in the browsing history

3.2.4 Download History

The following figure shows the QuickTimeInstaller.exe being downloaded from the ftp://jnec.edu.bt FTP site.

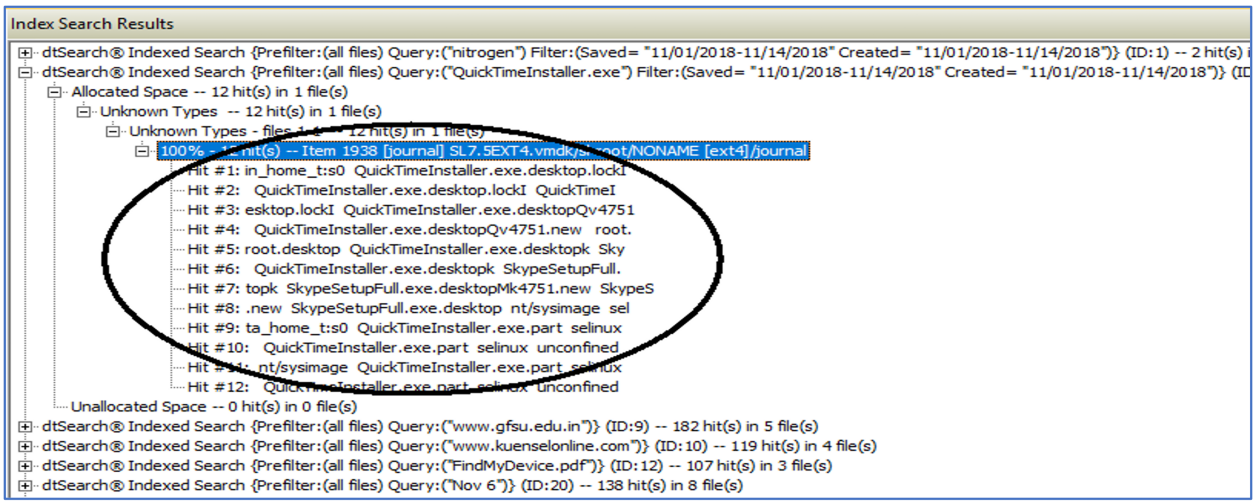


Figure 6: FTK showing QuickTimeInstaller.exe being downloaded from ftp://jnec.edu.bt

3.2.5 File Transfer History

The following figure shows four files Find My Device.pdf, WHOIS.pdf, WHOIS.docx, and FindMyDevice.docx being transferred.

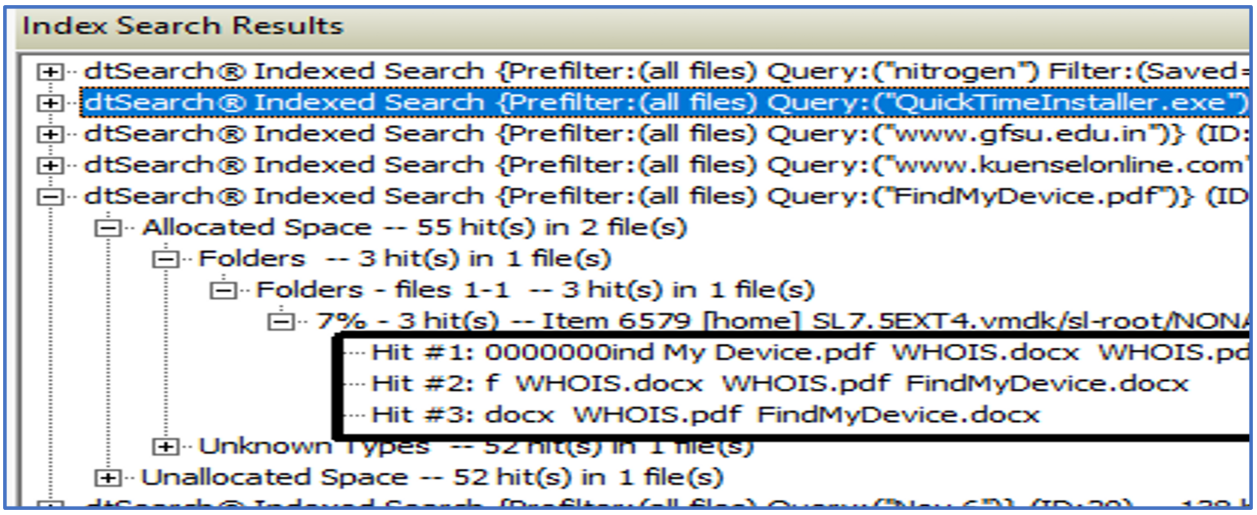


Figure 7: FTK shows four files being transferred

3.3 Analysis using Autopsy

To recover the artifacts, Autopsy 4.8.0 was installed and the evidence file in the vhd format was loaded. The Autopsy was able to analyse the evidence file but did not populate any pieces of evidence in the Extracted Contents category under the Results section. The artifacts had to be manually searched using the keyword search feature.

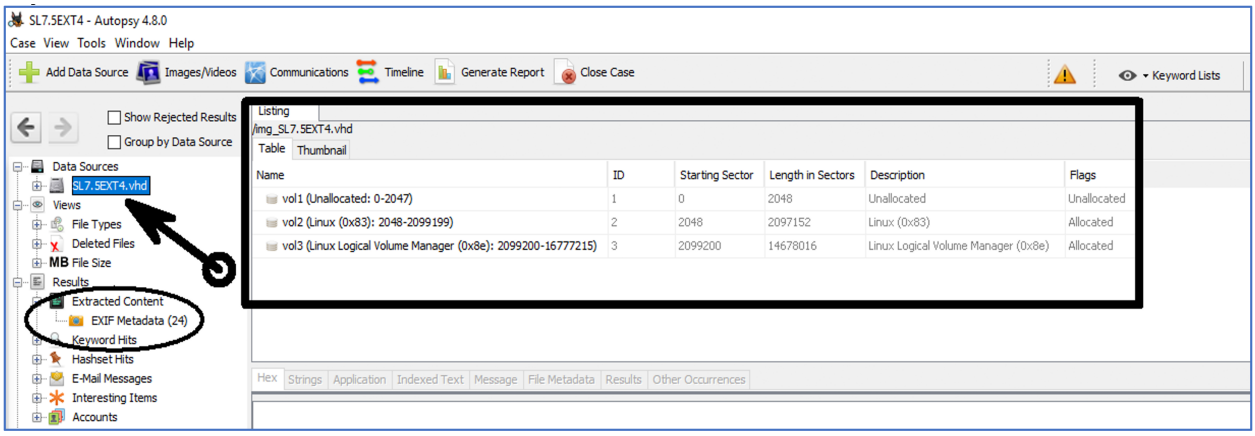


Figure 8: Image loaded in the vhd format in Autopsy

The Autopsy after loading and analysing the image of the Scientific Linux 7.5 (Operating System), could not populate results and hence the keyword search feature was used to fetch the probable evidence. The following details were found using the keyword search as indicated by Figure 9, Figure 10, Figure 11, Figure 12, Figure 13, Figure 14, and Figure 15.

3.3.1 Operating System Version and Installation Date

The following figure shows the Operating System as Scientific Linux 7.5 and the date of installation is indicated as Tuesday, 6th of November 2018 respectively.

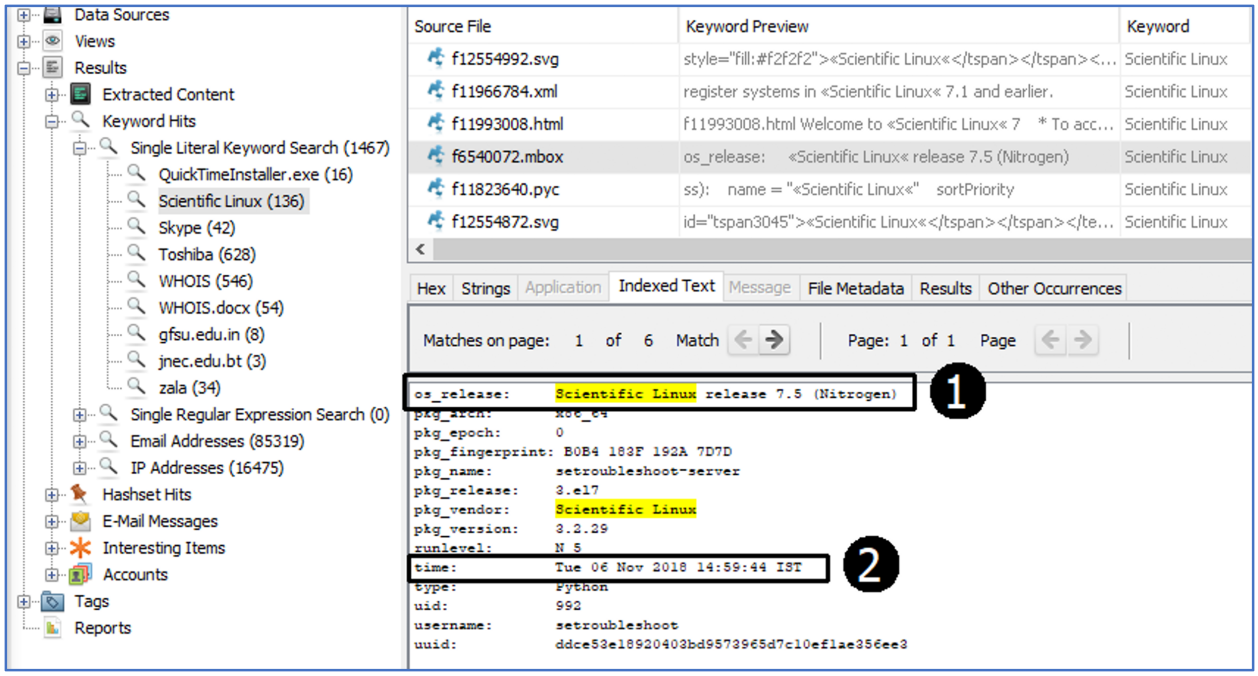


Figure 9: Autopsy showing OS name, version, and installation date

3.3.2 User Accounts Details

The details of the user account such as the root user and the normal user account which was present in the evidence file are being fetched as indicated in the following Figure 10.

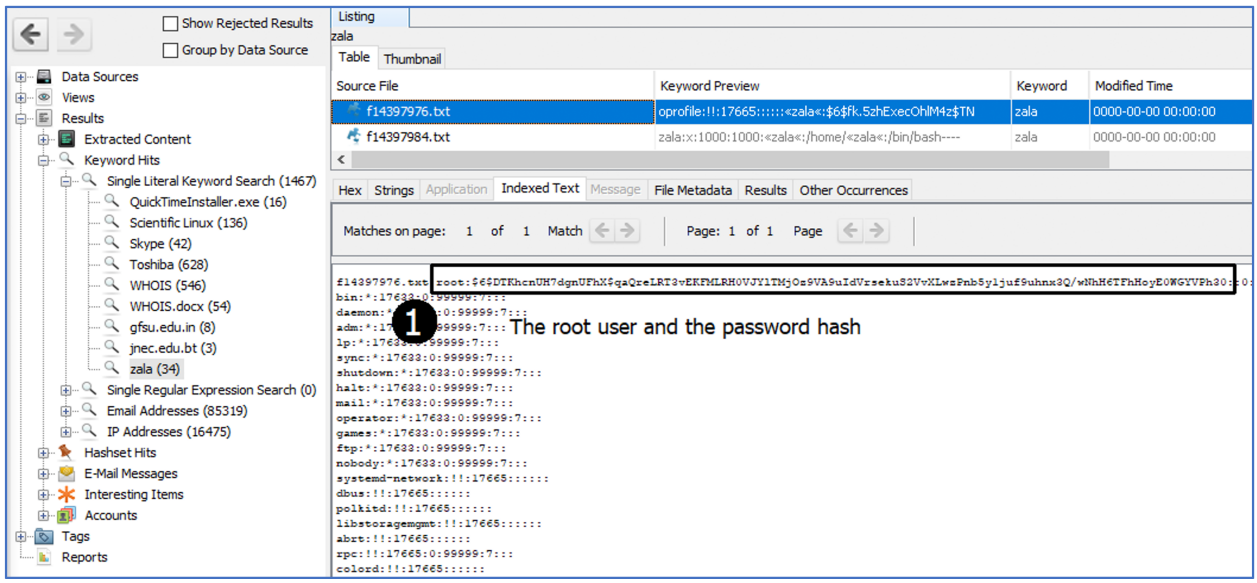


Figure 10: Autopsy showing root user and its password hash

3.3.3 Browsing History

The autopsy shows the websites and the FTP sites being browsed when it is being searched using the keyword feature. The websites http://www.gfsu.edu.in and http://www.kuenselonline.com, and also the FTP site ftp://jnec.edu.bt are being fetched from the browsing history as shown in the following figures respectively.

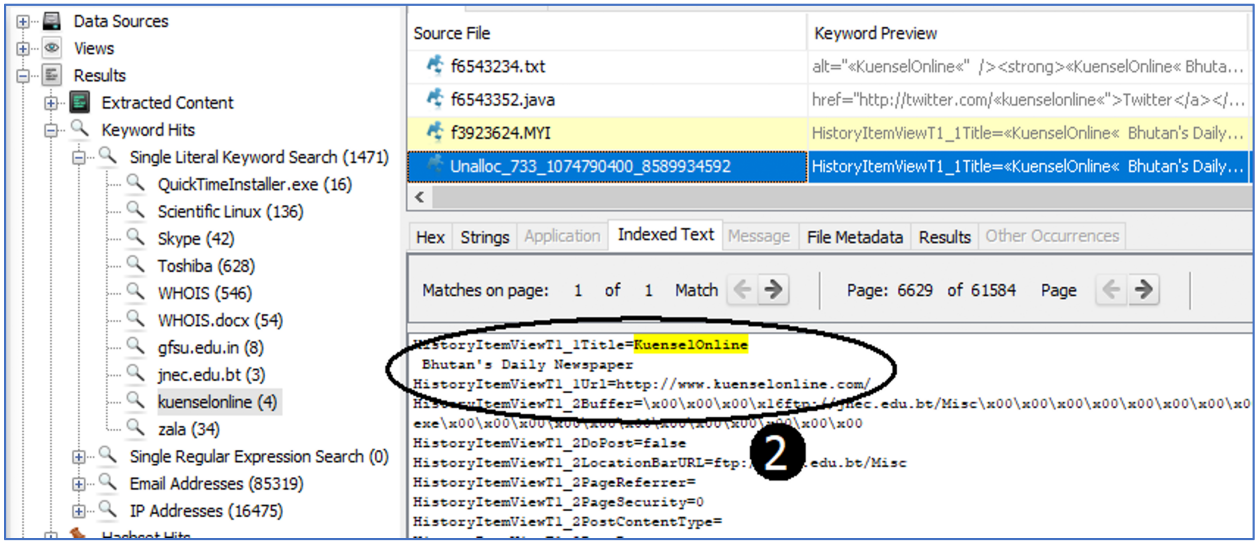


Figure 11: Autopsy showing www.kuenselonline.com in the browsing history

3.3.4 Download History

The following figure shows the QuickTimeInstaller.exe being downloaded from the ftp://jnec.edu.bt FTP site.

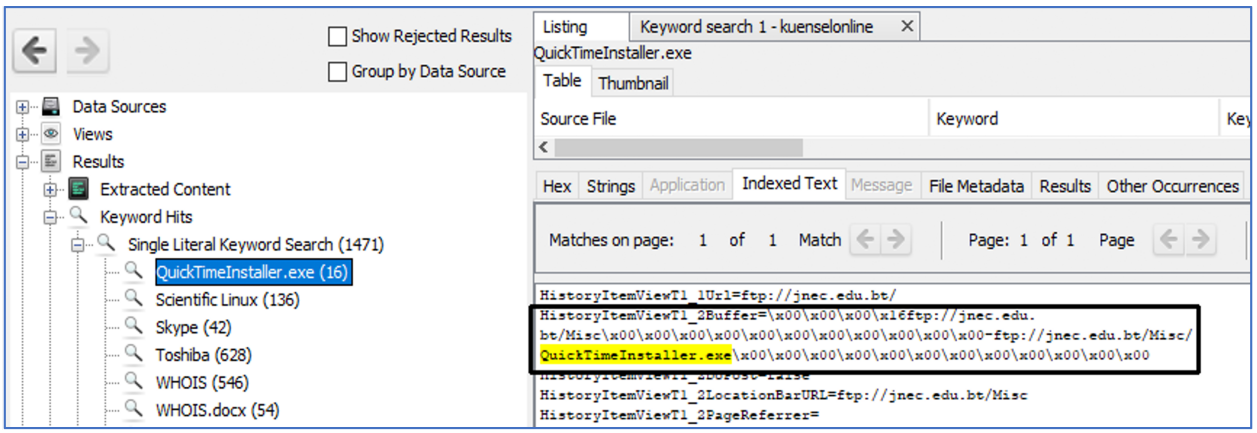


Figure 12: Autopsy showing QuickTimeInstaller.exe being downloaded from ftp://jnec.edu.bt

3.3.5 File Transfer History

The following figure shows four files "Find My Device.pdf", "WHOIS.pdf", "WHOIS.docx" and "FindMyDevice.docx" being transferred.

3.3.6 Deleted and Shredded Files (Recovery)

Although the files that are being removed using the rm command, overwritten and removed using the shred command are not being recovered, the command history indicates that the file "FindMy-Device.pdf" was removed and the file "WHOIS.docx" was overwritten five times and removed.

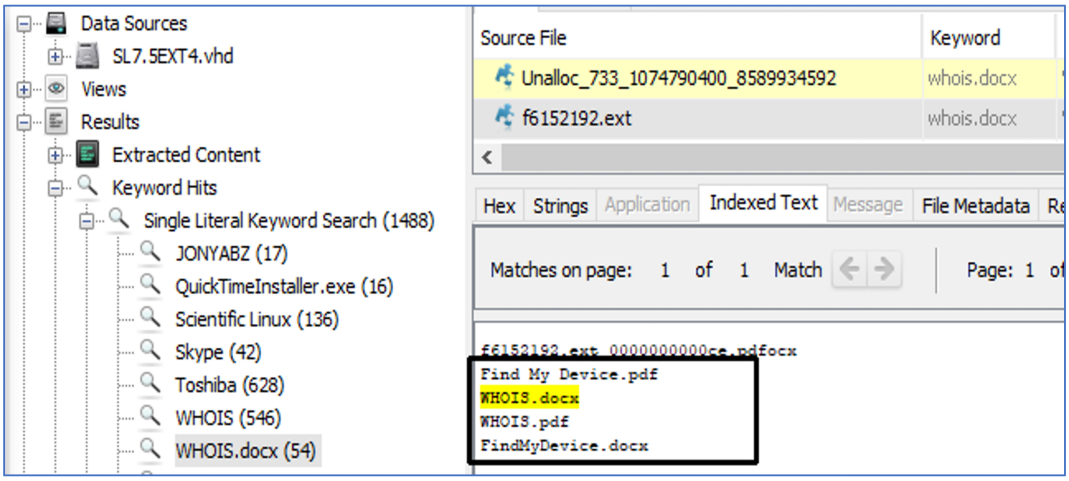


Figure 13: Autopsy showing four files being transferred

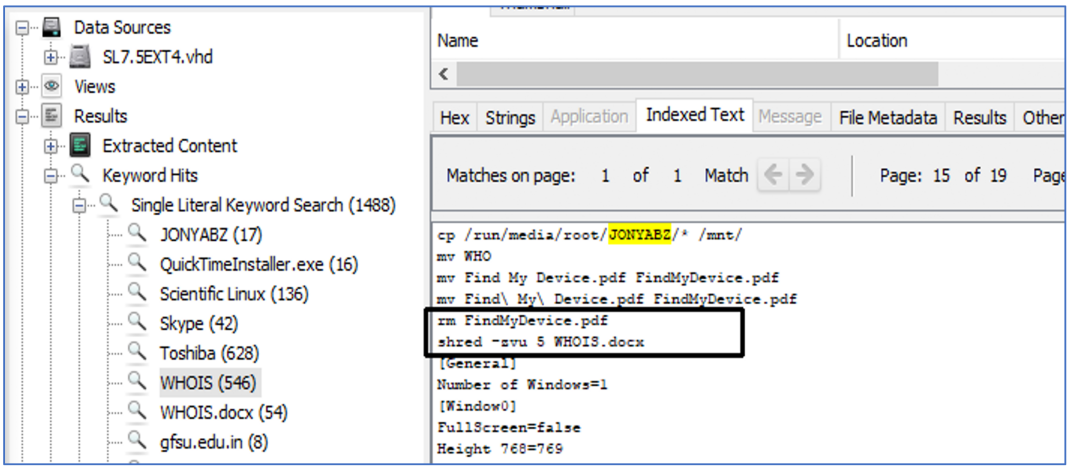


Figure 14: Autopsy showing files being removed and shredded

3.3.7 Attached USB Devices' Details

The Autopsy has shown that two storage devices have been connected to the system (1) External USB 3.0 with serial number 22223223272C manufactured by Toshiba company.

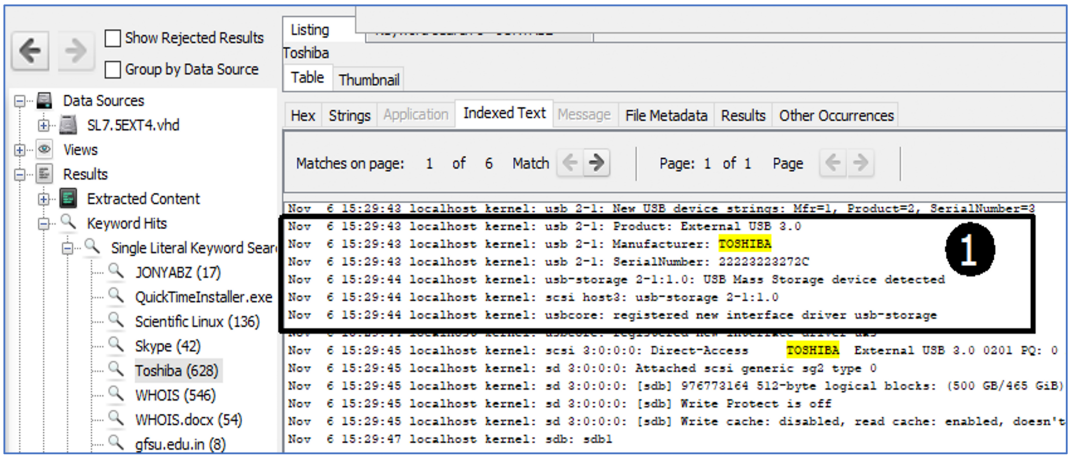


Figure 15: Autopsy showing External USB 3.0 attached

3.4 Analysis using Bulk Extractor

To extract the URL features from the evidence image file, bulk_extrcator version 6.2.1.10 was used from the Kali Linux. The image file in the raw format (dd) was fed into the bulk_extractor and was analyzed.

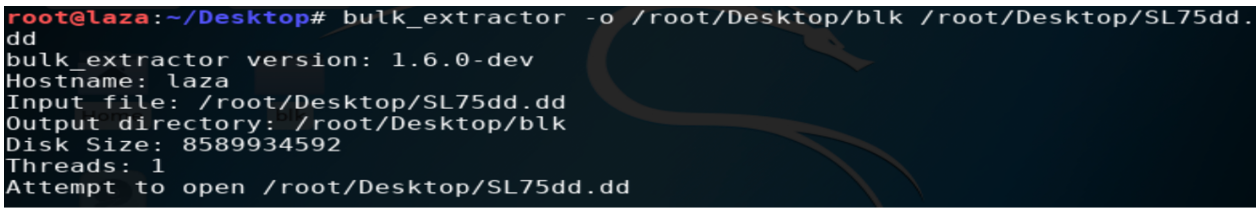


Figure 16: Image loaded in the dd format to bulk_extractor

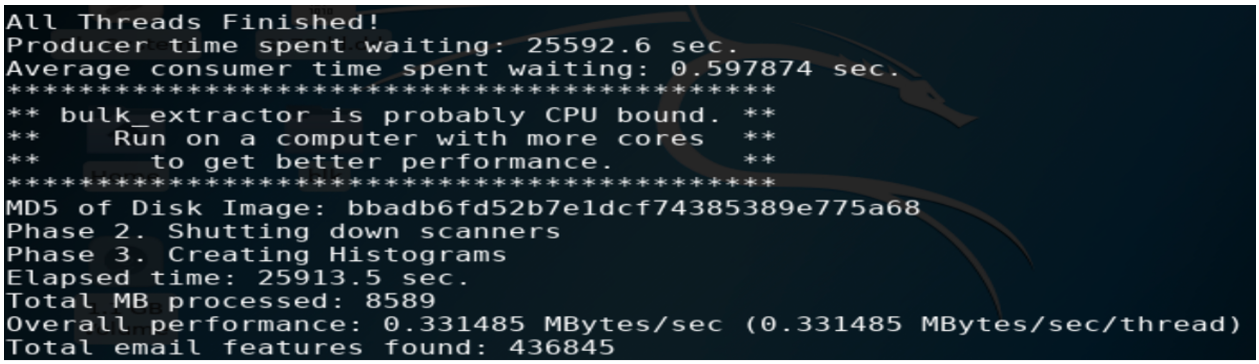


Figure 17: The image is scanned and the featured extracted

3.4.1 Browsing History Fetched using bulk_extractor

After scanning for the regular expressions, the bulk_extractor fetched the URLs which were browsed on the Scientific Linux 7.5 system.



Figure 18: Browsed URL www.kuenselonline.com being listed by bulk_extractor

3.5 Analysis using Scalpel

To recover the files from the evidence image, Scalpel from the Kali Linux was used and the image in dd format was fed to the Scalpel for recovery by using the command "scalpel /root/Desktop/SL75dd.dd -o /root/Desktop/scalpel" by being in the /etc/scalpel directory.

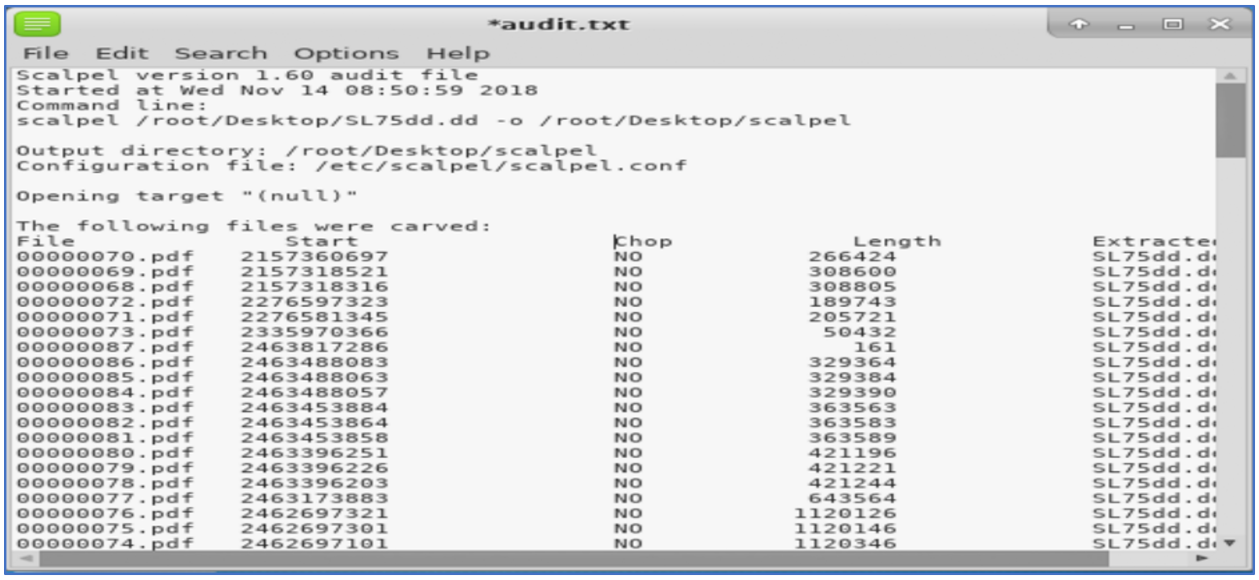


Figure 19: Summary of the carved file by Scalpel

After the scanning and carving, the carved files are categorized into .doc and .pdf and would be stored in the specified directory. However, the file names are not the actual file names; Scalpel is naming them with numeric values with either .doc or .pdf extensions.

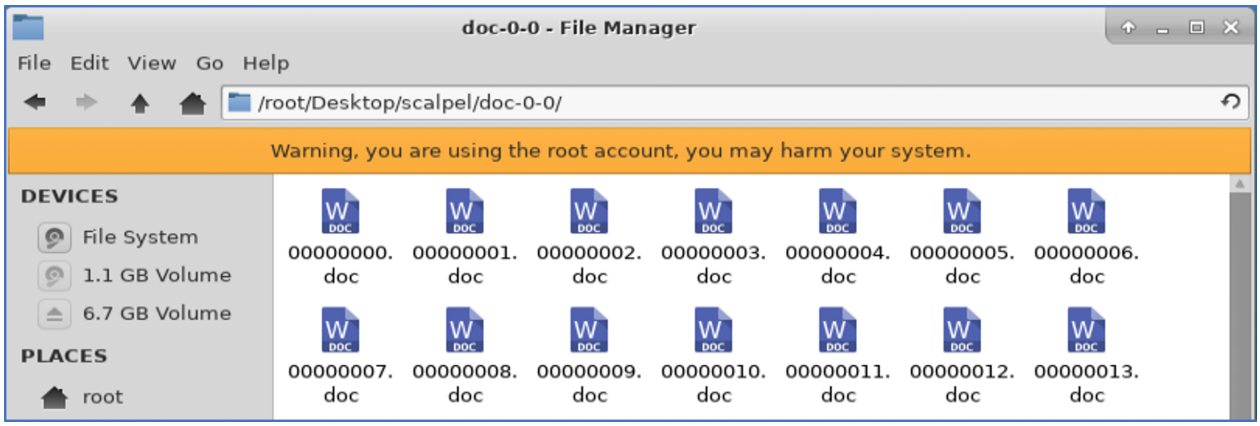


Figure 20: Carved doc files using the Scalpel

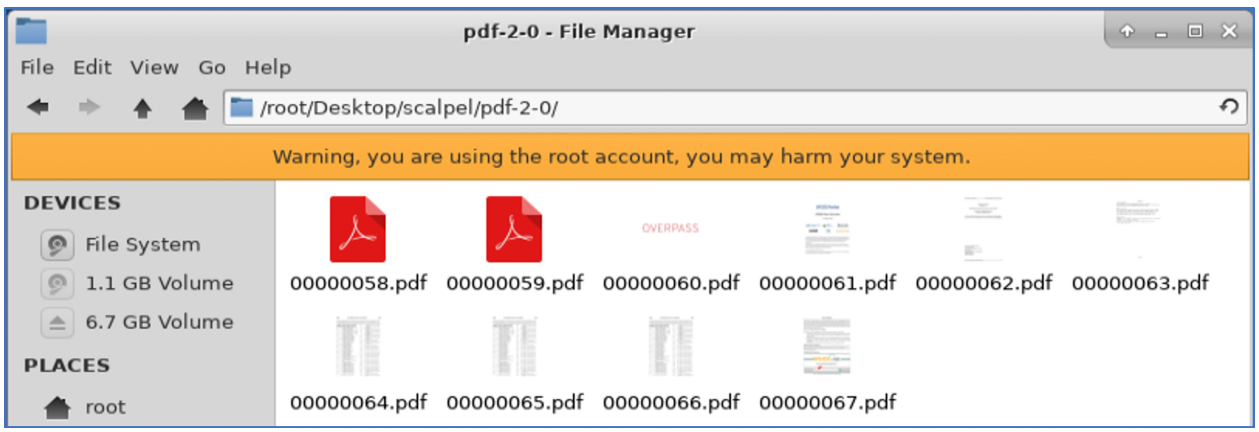


Figure 21: Carved PDF files using the Scalpel

3.6 Comparison Chart

The following comparison chart was derived after the attempt to examine the Scientific Linux 7.5 image file was made using the EnCase, FTK, Autopsy, Bulk_extractor, and the Scalpel forensic tools. Table 1. Comparison Chart of forensic tools' capability

Table 1: Comparison of Forensic Tools

Forensic Evidence	EnCase	FTK	Autopsy	Bulk Extractor	Scalpel
OS name and version	No	Yes	Yes	No	No
OS installation date	No	Yes	Yes	No	No
User account list	No	No	Yes	No	No
Browsing history	No	Yes	Yes	Yes	No
Download history	No	Yes	Yes	No	No
File transfer history	No	Yes	Yes	No	No
Recovery of resident files	No	Yes	Yes	Yes	Yes
Deleted and shredded files recovery	No	No	No	Yes	Yes
USB attached history	No	No	Yes	No	No

4 Conclusion

The findings suggest that commercial tools excel in user-friendliness, comprehensive support, and integration of advanced features. On the other hand, open-source tools have demonstrated commendable versatility, transparency, and adaptability, enabling forensic practitioners to tailor their approaches based on specific requirements. It is evident from the comparison chart that Autopsy and FTK are the two forensic tools that can be used to investigate crime involving the use of Scientific Linux. Commercial forensic tools such as EnCase and FTK are more inclined towards the use of investigating crimes involving Windows-based devices and prove less compatible with the Linux Operating System variant such as Scientific Linux. Therefore, with restraint, it is also concluded that the investigations involving the use of Linux-based operating systems can rely more on open-source tools such as Autopsy and the like. However, modular tools such as bulk_extractor and Scalpel can be involved in carrying out specific functionality such as recovering the deleted files.

This comparative analysis of Scientific Linux image forensics using both commercial and open-source tools has provided valuable insights into the strengths, weaknesses, and practical applications of these tools in the context of digital investigations. Importantly, this study has highlighted the need for a nuanced and context-specific selection of tools based on the nature of the investigation, available resources, and the specific requirements of operating system environments. The ideal approach may involve a judicious combination of commercial and opensource tools, capitalizing on their respective strengths to overcome the limitations of each. The insights gleaned from this study findings contribute to the broader discourse on optimizing digital forensic practices, emphasizing the importance of adaptability, collaboration, and a well-informed tool selection process for effective investigations.

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