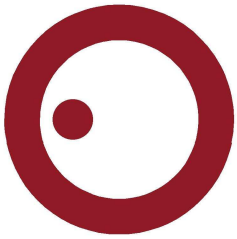

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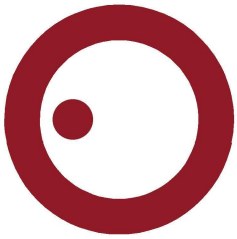
AUTOPSY – ENHANCED DISTRIBUTED FORENSIC ANALYSIS

PEDRO HENRIQUE GASPAR CORDEIRO FERREIRA

Leiria, Fevereiro de 2020

[December 13, 2019 at 17:25 – version 1.0]



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AUTOPSY – ENHANCED DISTRIBUTED FORENSIC ANALYSIS

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Número: 2180078

Relatório de estágio realizado sob orientação da Professora Doutora Marisa da Silva Maximiano (marisa.maximiano@ipleiria.pt).

Leiria, Fevereiro de 2020

[December 13, 2019 at 17:25 – version 1.0]

ACKNOWLEDGEMENTS

I would like to express appreciation for the opportunity provided by “VOID SOFTWARE, S.A.“ to work in an enterprise environment. I’d also like to thank my faculty advisor “Marisa da Silva Maximiano“ who provided much needed help writing this report in LaTeX 2_ε.I’m also thankful that Antonio Branco took time off his work to help me with so many minor details in my CSS layouts, as well as everyone one else in the company who provided me with everything I needed to succeed in my internship.

RESUMO

TODO.

A B S T R A C T

TODO.

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INTRODUCTION

1.1 DIGITAL FORENSICS

1.1.1 *Contextualization*

Forensic science is the use of scientific methods or expertise to investigate crimes or examine evidence that might be presented in a court of law.

The definition of digital forensics is directly related to the definition of computer forensics which is the collection, preservation, analysis, and presentation (*Digital Forensics for Legal Professionals*) of evidence stemming from digital sources for use in a legal matter using investigative processes, tools, and practices.

Digital forensics is the application of computer technology to criminal cases where evidence includes items that are created by digital systems.

Digital forensics, according to NIST, is the field of forensic science that is concerned with retrieving, storing and analyzing electronic data that can be useful in criminal investigations. This includes information from computers, hard drives, mobile phones and other data storage devices.

Digital forensic investigators face challenges such as extracting data from damaged or destroyed devices, locating individual items of evidence among vast quantities of data, and ensuring that their methods capture data reliably without altering it in any way.

Personal data should ultimately be attributable to an individual; however, making that attribution can be difficult due to the presence or absence of individualized user accounts, security to protect those user accounts, and the actual placement of a person at the same location and time when the data is created.

1.1.2 *Digital Evidence*

Digital evidence is any type of digital data with incriminating characteristics, which can result from any type of action preformed by a user, like transactions, recordings, or virtually any action preformed on a device.

Nowadays it's virtually impossible not to leave a digital track behind, since most of us carry and use devices capable of connecting to the internet.

The explosion of social media sites has created a whole new area of electronic evidence. Most people today are willing to share all kinds of information through social media platforms.

In order for electronic data to become digital evidence, it must be stored and be recoverable by a forensic examiner. One of the great challenges is not whether digital evidence may exist, but where the evidence is stored, getting access to that storage, and finally, recovering and processing that digital evidence for relevance within a civil or criminal action.

The potential storage options for electronic evidence has shifted from being only contained locally to being either located locally or remotely in what is called "The Cloud".

More and more everyday computing processes are moving to the Internet where companies offer software as a service. Software as a service means that the customer no longer has to install software on their computer, allowing access to the software remotely, and not storing any data locally.

1.1.3 *Processes and Procedures*

Digital forensics is the application of forensic science to electronic evidence in a legal matter.

While there are many different subdisciplines and many types of devices, communication, and storage methods available, the basic principles of digital forensics apply to all of them.

These principles encompass four areas:

1. Acquisition
2. Preservation

3. Analysis
4. Presentation

Each of these areas includes specific forensic processes and procedures.

1.1.3.1 *Acquisition*

Acquisition is the process of collecting electronic data. Seizing a computer at a crime scene or taking custody of a smartphone in a civil suit are examples of device acquisition, but the data must be extracted from these devices using specific procedures that equate to making a copy of the storage devices, while following strict rules to ensure the integrity of all the extracted data.

Since acquisition is the first interaction between the investigators and the evidence, it is the step where it's most likely to occur modifications of the contents of the seized devices, because turning on the device or extracting the data without following the right procedures can alter it's contents irreversibly.

1.1.3.2 *Preservation*

For evidence to be defendable in court it must be preserved properly. Preservation in the forensics context is the process of creating a chain of custody that begins before collecting the evidence and ends when the evidence is released. Any interference in the chain of custody can lead to issues regarding the validity of the evidence. Additionally, preservation includes maintaining the evidence in a safe environment, preventing intentional destruction with malicious purpose or accidental modification by unqualified people.

A chain of custody log allows proving that the integrity of the evidence has been maintained from seizure through presentation in court. It should contain entries for every time that a piece of evidence has been touched, including collection, storage transport, and any time the evidence is checked out for handling by any personnel.

1.1.3.3 *Analysis*

Analysis is the process of locating and categorizing items from evidence that has been collected in a case. Each case is unique as the circumstances surrounding each case can vary immensely, not only in the evidence being analyzed, but also in the approach used to perform the analysis. The analysis is the area where the

individual skills, tools used, and the training of the forensic examiner have the greatest impact on the outcome of the examination. Considering that electronic evidence appears in so many forms and comes from diverse locations and devices, the training and experience of the examiner has a much greater impact on the results of the examination.

Analysis of digital evidence is more than just determining whether a file exists on a hard drive, it involves finding out how that file got on the hard drive, and if possible, who put the file on the hard drive.

1.1.3.4 *Presentation*

Presentation of the examiner's findings is the last step in the process of forensic analysis of electronic evidence. This includes not only the written findings or forensic report, but also the creation of sworn statements, depositions of experts, and court testimony. There are no exact rules or standards for reporting the results of an examination. Each entity may have its own particular guidelines for reporting. However, forensic examination reports should be written clearly, concisely, and accurately, explaining what was examined, the tools used for the examination, the procedures used by the examiner, and the results of the examination. The report should also include the collection methods used, including specific steps taken to protect and preserve the original evidence and how the verification of the evidence was performed.

1.2 THE SLEUTH KIT

The Sleuth Kit (TSK) is a library and collection of command line tools that allow the investigation of disk images. The core functionality of TSK allows volume and file system data analysis. The plug-in framework allows incorporation of additional modules to analyze file contents and build automated systems. The library can be incorporated into larger digital forensics tools and the command line tools can be directly used to find evidence.

1.2.1 *Description*

The original part of Sleuth Kit is a C library and collection of command line file and volume system forensic analysis tools. The file system tools allows examining

file systems of a computer in a non-intrusive fashion. Because the tools do not rely on the operating system to process the file systems, deleted and hidden content can be shown.

The volume system tools allow examination of the layout of disks and other media. TSK supports DOS partitions, BSD partitions, Mac partitions, Sun slices, and GPT disks. With these tools, partition locations can be identified and extracted so that they can be analyzed with file system analysis tools.

When performing a complete analysis of a system, command line tools can become tedious. Autopsy is a graphical interface to the tools in TSK, which allows easier conduction of an investigation. Autopsy provides case management, image integrity, keyword searching, and other automated operations.

A complete analysis also requires more than just file and volume system analysis. However, a single tool can't provide support for all file types and analysis techniques. The TSK Framework allows tools to easily incorporate file analysis modules that were written by other developers.

TSK Analyzes raw, Expert Witness and AFF file system and disk images. It supports the NTFS, FAT, ExFAT, UFS 1, UFS 2, EXT2FS, EXT3FS, Ext4, HFS, ISO 9660, and YAFFS2 file systems.

1.2.2 *Search Techniques*

TSK allows listing allocated and deleted ASCII and Unicode file names, can display the details and contents of all NTFS attributes, can display file system and meta-data structure details, can create time lines of file activity, which can be imported into a spread sheet to create graphs and reports. TSK allows the lookup of file hashes in hash databases, it organizes files based on their type, and pages of thumbnails can be made from graphic images to facilitate quick analysis.

1.3 AUTOPSY

Autopsy is a digital forensics platform and a graphical interface to The Sleuth Kit along with other digital forensics tools. It is used by law enforcement, military, and corporate examiners to investigate what happened on a computer. It can even be used by anyone to recover photos from a camera's memory card.

Autopsy was designed to be intuitive out of the box. Installation is easy and wizards guide the user through every step. All results are shown in a single tree.

Autopsy was designed to be an end-to-end platform with modules that come with it out of the box and others that are available from third-parties. Some of the modules provide:

- Timeline Analysis - Advanced graphical event viewing interface;
- Hash Filtering - Flag known bad files and ignore known good;
- Keyword Search - Indexed keyword search to find files that mention relevant terms;
- Web Artifacts - Extract history, bookmarks, and cookies from Firefox, Chrome, Internet Explorer and Microsoft Edge;
- Data Carving - Recover deleted files from unallocated space;
- Multimedia - Extract EXIF metadata from pictures and videos and display these files;
- Indicators of Compromise - Scan a computer using STIX.

Autopsy runs background tasks in parallel using multiple cores and provides results as soon as they are found. It may take hours to fully search a drive, but the user will know in minutes if certain keywords were found in a specific folder.

Autopsy is free. As budgets are decreasing, cost effective digital forensics solutions are essential. Autopsy offers the same core features as other digital forensics tools and offers other essential features, such as web artifact analysis and registry analysis, that other commercial tools do not provide.

1.4 ALTERNATIVE SOFTWARE

1.4.1 *nuix*

Nuix Lab allows investigators to work efficiently on gigabyte to terabyte-sized investigations and beyond. It's ideal for local or small regional forensic labs struggling with the expanding volume, variety, and complexity of digital evidence and looking to build or upgrade a dedicated digital forensics facility.

If your resources are spread geographically or you're looking to facilitate greater collaboration across departments, the Nuix Lab breaks down evidence silos and

makes better use of existing team members and intelligence. Nuix software puts evidence into the hands of less technical reviewers or case officers sooner in the investigation.

The core technologies of the Nuix Lab, Nuix Workstation and Nuix Investigate, give digital forensic technicians and case investigators different lenses into the same case data. Investigators benefit from an easy-to-use browser experience where they can collaborate on the same data at the same time, creating efficiency and helping them share insights.

Implementing Elasticsearch as a data store for the Nuix Lab boosts your evidence processing, investigation, and intelligence capabilities. It's ideal for investigations that contain massive volumes of digital evidence and numerous digital exhibits; are conducted across multiple regions or jurisdictions, or need to cross-reference and correlate intelligence across multiple current and historical cases.

In addition, you can apply powerful artificial intelligence, machine learning, and analytics to supercharge your investigations. A Nuix Lab will ensure you find the right evidence, fast!

1.4.2 *EnCase Forensic*

EnCase Forensic enables you to quickly search, identify, and prioritize potential evidence, in computers and mobile devices, to determine whether further investigation is warranted. This will result in a decreased backlog so that investigators can focus on getting to case closed.

EnCase Forensic helps you acquire more evidence than any product on the market. You can collect from a wide variety of operating and file systems, including over 25 types of mobile devices with EnCase Forensic. Parse the most popular mobile apps across iOS, Android, and Blackberry devices so that no evidence is hidden. This is the flexibility needed to ensure you can complete your cases no matter where the potential evidence resides.

EnCase Forensic is unmatched in its decryption capabilities, offering the broadest support of any forensic solution. Encryption support includes products such as Dell Data Protection, Symantec, McAfee, and many more. You can further expand the decryption power of EnCase Forensic with Tableau Password Recovery — a purpose-built, cost-effective hardware solution to identify and unlock password-protected files.

The EnCase Forensic evidence processor provides industry-leading processing capabilities that can automate the preparation of evidence, making it easier to complete the investigation. Powered by an indexing engine built for scale and performance, you can automate complex queries across your varied evidence sources in one step saving time and increasing your efficiency.

The most important part of any investigation is your ability to analyze your evidence. EnCase Forensic is built with the investigator in mind, providing a wide range of capabilities that enables you to perform deep forensic analysis as well as fast triage analysis from the same solution. Built to help you do what you do best: find evidence and close cases.

EnCase Forensic provides a flexible reporting framework that empowers you to tailor case reports to meet your specific needs. With comprehensive and triage reporting options built in, you can create reports for a wide range of audiences and easily share them across your organization.

1.4.3 *Forensics Toolkit*

FTK is an award-winning, court-cited digital investigations solution built for speed, stability and ease of use. It quickly locates evidence and forensically collects and analyzes any digital device or system producing, transmitting or storing data by using a single application from multiple devices. Known for its intuitive interface, email analysis, customizable data views, processing speeds and stability, FTK also lays the framework so your solution can grow with your organization's needs for a smooth expansion.

All digital evidence is stored in one case database, giving teams access to the most current case evidence. It reduces the time, cost and complexity of creating multiple datasets. You won't experience failures associated with memory-based tools like you can with other products on the market. For example, if the GUI crashes, the processing workers can continue to process data. And best of all, there is continuous data transfer between AccessData's forensic and e-discovery solutions, allowing for true collaboration between all parties working on the case.

With customizable processing, you have the ability to establish enterprise-wide processing standards, creating consistency for your investigations and reducing the possibility of missed data. Since evidence is processed up front, you don't have to wait for searches to execute during the analysis phase. FTK is designed to provide

the fastest, most accurate and consistent processing with distributed processing and true multi-threaded/multi-core support.

FTK uses 100 percent of its hardware resources and is more reliable in the event of hardware or software glitches. You can also benefit from processing data faster since FTK uses all hardware resources!

Indexing is done up front, so filtering and searching are faster than with any other solution. FTK offers the flexibility to perform multipass data review and change indexing options without reprocessing your data. Whether you are in the investigating phase or performing document review you have a shared index file, eliminating the need to recreate or duplicate the file. Most importantly, you'll receive consistent search results regardless of whether you are searching in FTK or Summation. Social Analyzer allows you to view email communications at the domain level and drill down to the custodian level to see communications among specific individuals.

FTK allows users to create images, process a wide range of data types from forensic images to email archives and mobile devices, analyze the registry, crack passwords, and build reports—all within a single solution.

With the single-node enterprise, users can preview, acquire and analyze evidence remotely from computers on your network.

Automatically construct timelines and graphically illustrate relationships among parties of interest in a case. With Email, Social and File Visualization you can view data in multiple display formats, including timelines, cluster graphs, pie charts, geolocations and more, to help you determine relationships and find key pieces of information. Then generate reports that are easily consumed by attorneys, CIOs or other investigators.

Almost every investigation involves the analysis of Internet artifacts. Web browsing caches store records of sites a suspect has visited, web-based emails may help to prove intent or correlate other events and instant message conversations or social media sites can contain evidence. When evidence is processed, artifact files are categorized and organized so that you can easily see them.

Unlock files when you don't know the password with market-leading decryption password cracking and recovery.

Image detection technology recognizes flesh tones and auto-identifies more than 30,000 potentially pornographic images.

Available as an option to FTK, Cerberus is an automated malware triage platform solution designed to integrate with FTK. It's a first layer of defense against the risk of imaging unknown devices and allows you to identify risky files after processing your data in FTK. Then you can see which files are potentially infected and can avoid exporting them. Cerberus is one tool in your malware arsenal and helps you identify potentially malicious files.

Teams can:

- Determine both the behavior and intent of security breaches sooner by providing complex analysis prior to a full-blown malware attack.
- Strengthen security defenses and prevent malicious software from running with state-of-the-art technology called whitelisting.
- Take action sooner when security breaches occur; unlike other competitors, Cerberus doesn't rely on a sandbox or signature-based solutions.

1.5 PROPOSED SOLUTION

Este documento serve de orientação para o relatório da unidade curricular de Projecto Informático do Curso de Engenharia Informática da ESTG – IPLEIRIA. Como tal, é constituído por um conjunto predefinido de estilos a utilizar. Estes estilos devem ser utilizados sem serem alterados ou substituídos. Para começar facilmente a escrever o relatório, basta guardar uma cópia deste documento e substituir os campos e as secções de acordo com o projecto em questão.

Embora possa parecer uma abordagem demasiadamente descritiva para a escrita do relatório, as intenções pretendidas com este documento são:

- Focar os alunos na produção de conteúdos com qualidade, em vez de se preocuparem com formatações de tipos de letra, parágrafos, etc.;
- Ao fornecer um documento de orientação de estilos a Escola beneficia de um aspecto profissional e consistente da globalidade dos seus relatórios de projecto.

Quanto ao conteúdo de uma introdução, ele deve preparar o leitor para o resto do relatório. Deve conter o detalhe suficiente para que alguém das áreas de conhecimento envolvidas possa entender o assunto do trabalho. A maior parte das introduções contêm três partes para fornecer contexto ao trabalho: objectivos, âmbito e background do trabalho do projecto. Estas partes muitas vezes sobrepõem-se, e podem por vezes ser omitidas simplesmente porque não faz sentido incluir alguma delas.

É de extrema importância considerar os objectivos do trabalho e do relatório na introdução. Se os autores não entenderem bem os objectivos do trabalho, dificilmente o leitor os entenderá. As seguintes questões ajudam a pensar nos objectivos do trabalho e na razão da escrita do relatório:

1. O que foi descoberto ou provado?
2. Em que tipos de problemas se trabalhou?
3. Porque é que se trabalhou nestes problemas? Se o problema lhe foi atribuído, deve tentar-se saber as razões pelas quais os orientadores o formularam, e o que era suposto que os alunos aprendessem ao trabalharem neste problema;
4. Qual a razão da escrita deste relatório?
5. O que é que o leitor deve ficar a saber quando acabar de ler este relatório?

O âmbito deve indicar as áreas de conhecimento envolvidas e realçar a metodologia utilizada no trabalho de projecto. Referir o âmbito do projecto na introdução ajuda o leitor a perceber os parâmetros de entrada do trabalho e do relatório, bem

como a identificar as principais restrições consideradas (por exemplo "existem 5 Sistemas Operativos para trabalhar com determinado hardware, mas somente 3 foram considerados neste estudo"). As seguintes questões ajudam a pensar no âmbito do trabalho e do relatório:

1. De que forma foi abordado o problema, e qual a razão para tal abordagem?
2. Existiam outras abordagens óbvias que se poderiam ter adoptado ? Que limitações impediram que se tentassem outras abordagens?
3. Que factores contribuíram para a escolha da forma de como se abordou o problema, e qual o mais relevante nessa escolha?

A informação de background inclui os conhecimentos que o leitor deve possuir por forma a compreender o trabalho de projecto e correspondente relatório. Estes conhecimentos incluem a percepção de trabalhos prévios que motivaram a proposta do projecto corrente, ou referências a trabalhos teóricos e práticos relacionados com os objectivos e âmbito descritos acima. Devem remeter-se para anexos documentos que poderão ajudar na percepção de teorias, metodologias, técnicas ou ferramentas utilizadas no trabalho de projecto. As seguintes questões ajudam a pensar no background necessário para o trabalho e para o relatório:

1. Que factos deve o leitor conhecer para perceber o relatório?
2. Porque é que o projecto foi autorizado ou atribuído?
3. Quem já fez trabalho prévio para resolver o problema colocado pelo projecto?

Por fim, a introdução deve descrever como foi organizado o relatório, referindo brevemente o propósito de cada secção considerada no mesmo.

O resto deste documento dá uma breve perspectiva das partes seguintes que devem constar do relatório, bem como de outros aspectos de formatação.

2

HOST ENTITY CHARACTERIZATION

Escrever aqui tudo o que é trabalho relacionado com o projeto a ser desenvolvido. Neste capítulo as referências bibliográficas são extremamente importantes e podem ser feitas da seguinte forma (ver código fonte do LaTeX):

Para fazer uma citação no fim de uma frase: (Sims, 1992). Multiplas citações (Darwin, 1859; Koza, 1992)

Para fazer uma citação que serve também como sujeito dessa frase (por exemplo no início): Sims (1992)

Obter apenas o nome do autor: Sims

Obter apenas o título do obra: «Interactive evolution of dynamical systems»

Segundo Rudolph (2016) isto assim assado, bla .... *The minted package: Highlighted source code in LaTeX 2ε*

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- dsafsdfds
- dsfdsf

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2. sdfsfdsf
3. dsfdsfds

3

INTERNSHIP PROGRAMME

3.1 INTERNSHIP START

The internship started on September 2nd 2019, being planned to last for 9 months, ending on the 29th of May 2020.

The first day at the company was interesting, meeting most of the personalities of the workplace and getting set up with my work environment, consisting of a desk, chair, computer and 2 monitors.

As soon as the computer was properly configured with all the software needed the project became the main focus of my time at the company, making progress daily, sometimes just planning the architecture or analyzing the source code, sometimes just writing code, and sometimes a mix of both.

3.2 PROJECT PLANNING

Autopsy by itself is capable of providing a distributed solution for multi user collaboration, but it is very resource intensive and requires many complex configuration steps, and is also only fully supported on the Windows O.S.

The plan for this internship is to achieve the same kind of functionality provided by the original software, but without the dependency on harduous pre-configuration or hardware intensive requirements, resulting in needing only single capable server, and allowing the program to be used by multiple low capacity client devices using any web capable O.S.

To achieve that goal, the project will be an adaptation of the original Autopsy source code, into a server-client model, with the server developed in Java using the Quarkus framework, and the client developed in Javascript using the React framework.

The project is outlined to work in a multi user environment, allowing users to be assigned to teams and teams assigned to cases, and allowing multiple users to interact with a case simultaneously.

Autopsy has a major limitation, which is it only allows one case to be open at a time, ideally in this project we should find a workarround to allow working on multiple cases at once, but we feel like dedicating a server instance (which a single machine can have many virtualized within) per case is a good enough approach, though as future work the ability to spawn different containers as requested to work on different cases at once is an interesting challenge.

Given that the core features will be running in a remote server, it was decided that the addition of data sources to cases will be handled by an FTP client, allowing users to transfer image files to the respective data source directories of each case, and FTP access will be controlled according to each user's assigned cases.

3.3 AUTOPSY SOURCE CODE ANALYSIS

Autopsy is a digital forensics analysis software that is available as Open Source Software on GitHub.

With the goals set for this project, the source code was analyzed to understand which components need to be replicated and adapted in order to obtain the same logic flow.

The "Core" module is where the most important components are located, and after analysis it was concluded that the following directories contain relevant information:

- Actions: user interactions
- Casemodule: case class and other resources needed for the functioning of an autopsy case like data sources and artifacts
- Centralrepository: data persisted and accessed by multiple cases (Correlation Engine)
- Contentviewers: panels used for data representation
- Coordinationservice: configuration information distribution system
- Core: addition of command line options, system configurations and collaboration monitor
- Corecomponents: main user interface components

- Datamodel: all the entities needed to represent ingested data
- Datasourceprocessors: data processing utilities
- Directorytree: file explorer for ingested artifacts
- Ingest: utilities and events for data ingestion
- Keywordsearchservice: utility to search artifacts by keyword
- Modules: all the pre-included modules (data ingestion procedures)
- Progress: progress indicators and similar classes
- Python: resources needed for the functioning of the Jython language
- Rejview: resources used to analyse Windows registry
- Report: report generator
- Timeline: recent addition to Autopsy, allows visualization of artifacts in temporal chart, only available for Windows Operating System

The "KeywordSearch" module is also of critical importance as it provides one of the most meaningful features which is filtering all the artifacts in a case with a keyword search using the Apache Solr search platform, which indexes the text contents of all the artifacts and allows extremely fast searching through a large amount of data.

3.4 DEVELOPMENT

3.4.1 *Management Entities*

As a first step in the development, the different persisted entities were created, which are Users, Teams, and Cases. All the endpoints for actions involving these entities were created, resulting in the ability for the client program to interact with these entities and modify their relationships and other variables. For these functionalities there are two roles associated, the Manager role allows manipulation of the existing entities while the Investigator role only has access to his own information and the teams and cases he was assigned to. For these interactions, it was decided to create a drag and drop interface, which allows users to be dragged into teams and teams dragged into cases. All these entities are listed side by side and each have their own options and filtering input, as can be observed in Figure 1.

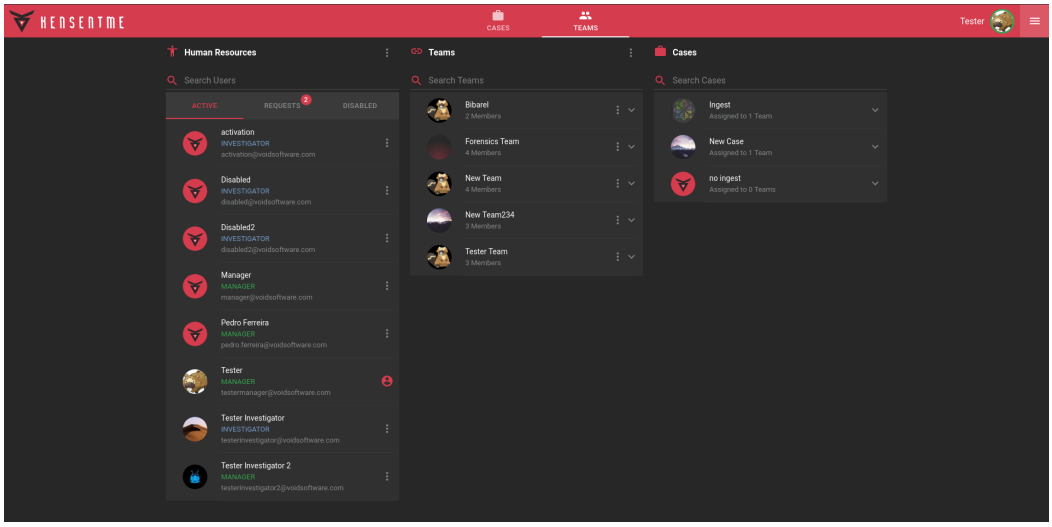

Figure 1: Entity Management Interface

Users can change their own profile picture, while Managers can also change any team or case's display picture. Managers can add new users to the platform, can approve membership requests, can enable/disable user accounts and can create new teams. When a user is added by a Manager or his membership request is approved he must define a password while activating his e-mail account.

3.4.2 *Basic Autopsy Functionalities*

Then the most basic functionality from Autopsy was adapted, the ability to open an autopsy case. For this some elements of the original Casemodule package were adapted, and after that all the other similar actions like closing, creating and deleting cases were also adapted.

Autopsy cases have a case file containing case metadata, which allows the program to connect to the right database when the case is open, this database is also present in a file inside the filesystem, which uses the SQLite database engine, so for the cases to be usable in the server these files must also be present in the server, which resulted in the creation of a directory within the server called "Server Repository", contaning all the different cases created within the application. This same directory will also be used to store data sources that are added to cases, which will be added through FTP protocol.

Later in the development there was the need to create an aditional directory inside the "Server Repository" called "Central Repository" which contains the database used by the Correlation Engine to ingest data that can be queried by any case.

3.4.3 *Ingested Results Presentation*

Ingested results are the items present inside the provided data sources, Autopsy runs multiple modules on each data source and extracts these results using the Sleuth Kit, extracted results can either be a file instance or an artifact (which is something that corresponds only to a piece of information inside a file).

The ingested results are presented in three different containers, one taking the shape of a file explorer, allowing exploration of the structure of all the results, one taking the shape of a table, presenting all the contents of the result selected from the explorer, and one taking the shape of a content viewer, allowing visualization of the data contained inside the result selected from the table, as can be seen in Figure 2.

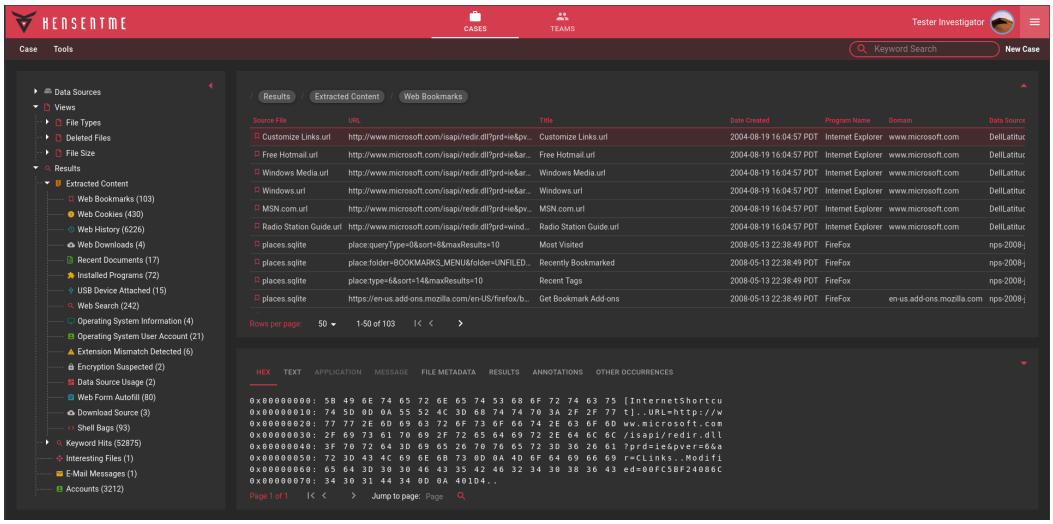

Figure 2: Ingested Results Presentation

The layout for the ingested results presentation, and for all the case related actions, was based on the original Autopsy layout, allowing each container to be resized as needed, allowing the user to focus on the information that is most important to him.

O corpo do relatório compõe, normalmente, a parte mais extensa do relatório, e contém todos os conteúdos necessários para que o leitor perceba o assunto do mesmo. Estes conteúdos incluem detalhes, dados, resultados de teste, factos e conclusões. O que incluir exactamente no corpo do relatório e como será organizado é determinado pelo contexto do trabalho desenvolvido. Geralmente, o corpo do relatório inclui 7 secções distintas:

1. Uma secção para teorias, modelos e hipóteses. Esta secção tem uma maior proeminência em artigos de investigação, onde é sugerida uma hipótese (contribuição) inovadora. Esta secção deve ser omitida para o caso de trabalhos mais práticos, cuja elaboração não origine uma contribuição inovadora, mas sim num produto de aplicação de tecnologias e metodologias;
2. Uma secção onde são discutidas as tecnologias, metodologias, ferramentas e técnicas utilizadas, e a forma como foram adequadas para se fazerem cumprir com os objectivos do trabalho. Algumas questões que esta secção deve procurar responder incluem:
   - Que equipamentos de hardware e ferramentas de software foram utilizados para o desenvolvimento do trabalho?
   - Qual a metodologia de desenvolvimento foi adoptada, e como é que ela se reflecte em termos de protótipos, modelos, diagramas, código, testes e documentação, de acordo com os objectivos do projecto? Sugere-se a utilização de exemplos no corpo do relatório, remetendo para anexos a descrição dos produtos intermédios completos;
   - Como foi planeado o trabalho, em termos de sequenciamento de actividades, recursos necessários, estimativas de tempo, e produtos intermédios., de acordo com a metodologia de desenvolvimento adoptada?
3. Uma secção na qual se apresentam e interpretam os resultados da elaboração do trabalho. A apresentação dos resultados finais do trabalho deve contrapor-se com os objectivos iniciais do projecto, e deve ser acompanhada de uma avaliação comprovada, por exemplo, através de testes elaborados e devidamente documentados. Deve também procurar-se quantificar o grau de satisfação dos requisitos do problema do projecto, através da exposição de funcionalidades não cumpridas ou cumpridas parcialmente (por exemplo, incluir uma lista de bugs de uma aplicação de software desenvolvida), bem como funcionalidades que extrapolam os objectivos iniciais do projecto;

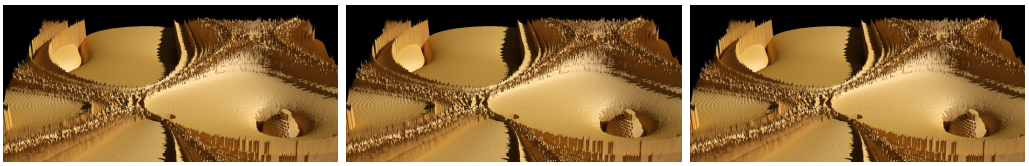

Figure 3: Imagem composta por três figuras em ficheiros separados

4. Uma secção de conclusões, onde são resumidos os principais resultados do trabalho e onde se usufrui de uma outra hipótese de expressar a sua qualidade/relevância através de um resumo conciso e coerente com o trabalho desenvolvido. É também o local onde se devem referir quais as principais forças e fraquezas do trabalho desenvolvido.

5. Uma secção de trabalho futuro, onde se devem propor possíveis desenvolvimentos futuros para colmatar as deficiências e lacunas identificadas atrás, ou simplesmente para evoluir o produto do trabalho desenvolvido;

6. Uma secção para referências bibliográficas, onde cada referência deve incluir, no mínimo, o nome dos seus autores, o título, data de publicação (ou de acesso, para o caso de URLs) e o tipo de documento (livro, artigo, website, etc.);

7. Uma secção para anexos, para a colocação dos produtos finais ou intermédios do projecto, por forma a não interromper a linha de desenvolvimento adoptada para a escrita da introdução e corpo do relatório. Deve ser utilizado um cabeçalho do estilo Heading 1 para identificar cada uma destas secções.

3.5 ESTILOS

O LaTeX 2$_\varepsilon$ trata da formação, apenas temos de usar as tags correctas. Seguem-se alguns exemplos. A Figura 3 é constituída por 3 imagens em ficheiros **.jpg** separados. A Figura 4 é constituída apenas por um ficheiro e ocupa 50% da largura de uma linha de texto.

Na Tabela 1 temos um exemplo de uma tabela onde existem linhas que ocupam mais do que uma linha da tabela.

As técnicas evolutivas baseiam-se em algoritmos bio-inspirados que aplicam a teoria de Darwin (Darwin, 1859). Esta defende a evolução natural das espécies onde os organismos vivos são recompensados, através da sobrevivência e da propagação dos seus próprios genes aos sucessores. Actualmente existem quatro classes principais de algoritmos evolutivos: Algoritmos Genéticos (AG) (Holland, 1975), Estratégias

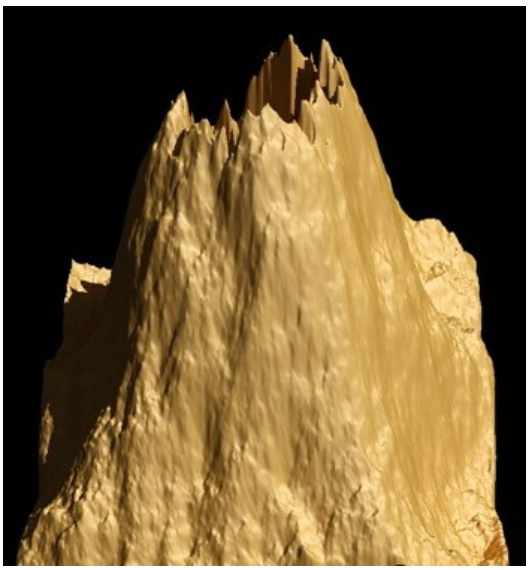

Figure 4: Vulcão

Table 1: Floating point benchmark. $\mathbf{R}_{max}$: the performance in Gflops for the largest problem run on a machine; $\mathbf{N}_{max}$: the size of the largest problem run on a machine; $\mathbf{N}_{1/2}$: the size where half the R_{max} execution rate is achieved; $\mathbf{R}_{peak}$: the theoretical peak performance in Gflops for the machine

Linpack Benchmark (Full precision)	Proc. or Cores	$\mathbf{R}_{max}$ GFlops	$\mathbf{N}_{max}$ Order	$\mathbf{N}_{1/2}$ Order	$\mathbf{R}_{peak}$ GFlops
Thinking Machine CM-5	32	1,900	9216	4096	4
Pentium 4 3.0 GHz	1	4,730	7600	365	6
IBM Cell BE 3.2 GHz	9	98,05	4096	1536	204,8 (32 bits) 14,6 (64 bits)

Evolutivas, Programação Genética (GP) (Koza, 1992) e Programação Evolutiva. Todos os algoritmos evolutivos mantêm uma população de soluções candidatas sobre a qual efectuam uma pesquisa para determinar os indivíduos mais fracos. De acordo com um determinado critério, estes são substituídos por outros gerados através de operadores aplicados aos melhores indivíduos da população, criando assim uma nova geração. Este processo é repetido sobre sucessivas gerações até se encontrar uma boa solução, que pode não ser a óptima.

Existem vários trabalhos e até video jogos que usam algoritmos evolutivos (Sims, 1992; Wikipedia, 2007).

3.6 INCLUIR CÓDIGO FONTE

Nas Listagens 1 e 3 temos um exemplo da inclusão de código fonte diretamente a partir do ficheiro fonte. Para mais informação ler o Manual da packge minted (Rudolph, 2016). Nestes exemplos a formação foi configurada no ficheiro `config.tex` (procurar por `minted`).

Listagem 1: Código fonte C com sintaxe colorida

```c
#include <stdio.h>
int main()
{
    int i, n, t1 = 0, t2 = 1, nextTerm = 0;

    printf("Enter the number of terms: ");
    scanf("%d", &n);

    printf("Fibonacci Series: ");

    for (i = 1; i <= n; ++i)
    {
        // Prints the first two terms.
        if(i == 1)
        {
            printf("%d, ", t1);
            continue;
        }
        if(i == 2)
        {
            printf("%d, ", t2);
            continue;
        }
        nextTerm = t1 + t2;
        t1 = t2;
        t2 = nextTerm;
        printf("%d, ", nextTerm);
    }
    return 0;
}
```

Listagem 2: Código fonte Bash que ocupa mais que uma página

```
#!/bin/bash
# Simple line count example, using bash
#
# Bash tutorial:
↪ http://linuxconfig.org/Bash_scripting_Tutorial#8-2-read-file-into-bash-array
# My scripting link: http://www.macs.hw.ac.uk/~hwloidl/docs/index.html#scripting
#
# Usage: ./line_count.sh file
# --------------------------------------------------------------------------

# Link filedescriptor 10 with stdin
exec 10<&0
# stdin replaced with a file supplied as a first argument
exec < $1
# remember the name of the input file
in=$1

# init
file="current_line.txt"
let count=0

# this while loop iterates over all lines of the file
while read LINE
do
    # increase line counter
    ((count++))
    # write current line to a tmp file with name $file (not needed for counting)
    echo $LINE > $file
    # this checks the return code of echo (not needed for writing; just for demo)
    if [ $? -ne 0 ]
     then echo "Error in writing to file ${file}; check its permissions!"
    fi
done

echo "Number of lines: $count"
echo "The last line of the file is: `cat ${file}`"

# Note: You can achieve the same by just using the tool wc like this
echo "Expected number of lines: `wc -l $in`"

# restore stdin from filedescriptor 10
# and close filedescriptor 10
exec 0<&10 10<&-

#!/bin/bash
# Simple line count example, using bash
#
# Bash tutorial:
↪ http://linuxconfig.org/Bash_scripting_Tutorial#8-2-read-file-into-bash-array
# My scripting link: http://www.macs.hw.ac.uk/~hwloidl/docs/index.html#scripting
#
# Usage: ./line_count.sh file
```

```
# ------------------------------------------------------------------------------

# Link filedescriptor 10 with stdin
exec 10<&0
# stdin replaced with a file supplied as a first argument
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file="current_line.txt"
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# this while loop iterates over all lines of the file
while read LINE
do
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    # write current line to a tmp file with name $file (not needed for counting)
    echo $LINE > $file
    # this checks the return code of echo (not needed for writing; just for demo)
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     then echo "Error in writing to file ${file}; check its permissions!"
    fi
done

echo "Number of lines: $count"
echo "The last line of the file is: `cat ${file}`"

# Note: You can achieve the same by just using the tool wc like this
echo "Expected number of lines: `wc -l $in`"

# restore stdin from filedescriptor 10
# and close filedescriptor 10
exec 0<&10 10<&-
```

Também é possível incluir código diretamente no ficheiro LaTeX 2_ε, como no exemplo em baixo. A numeração das linhas é importante para ser possível referir o número da linha numa descrição.

Listagem 3: Código fonte Python com sintaxe colorida

```
import numpy as np

def incmatrix(genl1,genl2):
    m = len(genl1)
    n = len(genl2)
    M = None #to become the incidence matrix
    VT = np.zeros((n*m,1), int)  #dummy variable

    #compute the bitwise xor matrix
    M1 = bitxormatrix(genl1)
    M2 = np.triu(bitxormatrix(genl2),1)

    for i in range(m-1):
        for j in range(i+1, m):
            [r,c] = np.where(M2 == M1[i,j])
            for k in range(len(r)):
                VT[(i)*n + r[k]] = 1;
                VT[(i)*n + c[k]] = 1;
                VT[(j)*n + r[k]] = 1;
                VT[(j)*n + c[k]] = 1;

                if M is None:
                    M = np.copy(VT)
                else:
                    M = np.concatenate((M, VT), 1)

                VT = np.zeros((n*m,1), int)

return M
```

4

CRITICAL ANALYSIS AND PROPOSED IMPROVEMENTS

O uso do LaTeX 2$_\varepsilon$ permite-nos focar no essencial: o conteúdo, a formatação é tratada de forma automática.

Para mais informações sobre o LaTeX 2$_\varepsilon$ aconselha-se a consulta do livro *The Not So Short Introduction to LaTeX 2$_\varepsilon$* Oetiker et al., 2000.

Para a gestão de referências bibliográficas aconselha-se o JabRef.

5

CONCLUSIONS

O uso do LaTeX 2$_\varepsilon$ permite-nos focar no essencial: o conteúdo, a formatação é tratada de forma automática.

Para mais informações sobre o LaTeX 2$_\varepsilon$ aconselha-se a consulta do livro *The Not So Short Introduction to LaTeX 2$_\varepsilon$* Oetiker et al., 2000.

Para a gestão de referências bibliográficas aconselha-se o JabRef.

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APPENDICES

APPENDIX A

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A.1 APPENDIX SECTION TEST

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Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris.

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Table 2: Autem usu id.

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A.2 ANOTHER APPENDIX SECTION TEST

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B

APPENDIX B

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D E C L A R A Ç Ã O

Declaro, sob compromisso de honra, que o trabalho apresentado nesta dissertação, com o título *"AUTOPSY – Enhanced distributed forensic analysis"*, é original e foi realizado por Pedro Henrique Gaspar Cordeiro Ferreira (2180078) sob orientação de Professora Doutora Marisa da Silva Maximiano (marisa.maximiano@ipleiria.pt).

Leiria, Fevereiro de 2020

Pedro Henrique Gaspar Cordeiro Ferreira