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Prototype Digital Forensics Repository

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PROTOTYPE DIGITAL FORENSICS REPOSITORY

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Abstract

The explosive growth in technology has led to a new league of a crime involving identity theft, stealing trade secrets, malicious virus attacks, hacking of DVD players, etc. The law enforcement community which has been trained to deal with traditional form of crime, is now being trained in a new realm of Digital Forensics. Forensics investigators have realized that often the most valuable resource available to them is experience and knowledge of fellow investigators. But there is seldom an explicit mechanism for disseminating this knowledge. Hence the same problems and mistakes continue to resurface and the same solutions are re-invented.

In this Thesis we design and create a knowledge base, a Digital Forensics Repository, to support the sharing of experiences about the Forensics Investigation Process. It offers capabilities such as submission of lessons, online search and retrieval which will provide a means of querying into an ever increasing knowledge base.

Chapter 1

Introduction

1.1 Background

With the wide use of Technology, electronic devices are becoming increasingly commonplace in society. Along with the widespread use also comes widespread abuse of electronic devices ranging from trivial hacking of DVD players to more serious crimes such as identity theft, stealing trade secrets, malicious virus attacks, etc. The rate at which electronic crime is increasing is putting a severe strain on the already limited resources used to investigate and solve the same. The law enforcement community which has been trained to deal with the more traditional form of crimes is now being trained in a whole new field of digital forensics. But even the most successful forensics training can only give common sense about computers and other digital devices. Forensics investigators meet new challenges with very new case. Every new case may involve a new source of digital evidence. Sources of digital evidences include many more than

- PDA
- Cell Phones
- Computers
- USB Flash Cards
- FAX Machines
- Telephones/Answering machines,
- Copiers,
- Video game systems,
- GPS devices,
- Digital cameras

Forensics technicians and investigators have realized that very often the most valuable resource available to them is the experience and knowledge of fellow technicians and

investigators. The experiences of every forensics technician and investigator contain valuable information. But there is seldom an explicit mechanism for disseminating this knowledge. As a consequence, the same problems and mistakes continue to resurface and the same solutions are re-invented often after consumption of already scarce resources such as time, money and effort. What is missing is a knowledge base that can act as a repository of information and a means to provide a widespread and an easy access to this knowledge base.

1.2 Objectives

The preservation, identification, extraction, documentation, and interpretation of the information stored within these devices for evidentiary analysis [13] is the province of the digital forensics specialist. The goal of maintaining a repository of “lessons learned” during the forensics investigation process is to collect information about experiences that will discourage the use of work practices that lead to undesirable outcomes and encourage the use of work practices that lead to desirable outcomes. Also, the system should be able to gather information from already available resources such as the Web.

1.3 Approach

In this Thesis we design and create a knowledge base, a digital forensics Repository, to support the sharing of experiences about the forensics investigation Process. It is a web-based application for storing “lessons learned”. The prototype is located at [14]. The prototype repository offers the following capabilities:

- The prototype repository allows three levels of authorization

- Collecting the lessons
- Storing and maintaining the lessons
- Retrieving and using the lessons
- Book marking lessons
- Provides infrastructure for RSS feeds
- Allows users to rate lessons
- Allows users to post questions and get help from other users
- Search the available resources on the web such as Google, Yahoo groups and other forensics sites
- Allows users to create lessons from these available resources

1.4 Organization

The remaining chapters are organized as follows:

Chapter 2 introduces the science of digital forensics and the rising need for digital forensics. Chapter 3 describes the process of investigation in digital forensics. Chapter 4 gives an overview of the related work done in this area. Chapter 5 gives a detailed introduction to the technologies used in this implementation. Implementation details are discussed in Chapter 6. Chapter 6 also explains the functional architecture, system architecture and database design. Chapter 7 contains the conclusion and future work. Chapter 8 gives a list of references.

Chapter 2

Digital Forensics

2.1 History of Forensics

Forensic science is the principles and techniques that identify evidence at a crime scene. In 1784, an Englishman was convicted of murder when a torn piece of newspaper that held the murder weapon matched a piece in his pocket - the first documented use of physical evidence. In 1835, Scotland Yard's Henry Goddard first used bullet comparison to catch a killer by tracing the bullet back to its mold.

2.2 Computer Forensics

Computer forensics is about evidence from computers that is sufficiently reliable to stand up in court and be convincing. Computer crime covers a wide range of criminal activity, from stealing trade secrets to fraud, identity theft to malicious virus attacks. Computer forensics is used to conduct investigations into computer related incidents, whether the incident is an external intrusion into your system, internal fraud, or staff breaching your security policy.

2.3 Need for Digital Forensics

Digital Forensics is probably a better term than Computer Forensics because many devices beyond those traditionally called “computers” are involved in today’s world. Digital devices are becoming increasingly commonplace in society, and can be found

almost everywhere. As digital devices proliferate so does criminal activity utilizing them. While the proliferation of new techno-gadgets has perhaps improved the quality of life for society at large, they have stretched resources to the breaking point within the law enforcement community. Now, many areas of law enforcement are turning to computer forensics experts to provide evidence across a wide range of crimes which involve computers or other digital devices. Civil proceedings also use computer forensics. Civil court cases might rely on computer records and data in determining the outcome of divorce, discrimination or harassment cases. Insurance companies use computer forensic evidence in possible cases of accident fraud, or arson and workman compensation cases. Corporations hire computer forensics experts to help discover evidence in sexual harassment, embezzlement, wrongful termination, theft and other kinds of corporate crimes. Security Agencies like Secret Service, CIA, FBI, and NSA use digital forensics in anti-terrorism efforts.

2.4 Sources of Digital Evidences

Sources of digital evidences include:

- Email
- Digital files or documents or images
- Chat logs, illegally copied software or other copyrighted material
- Contraband (e.g., child pornography)
- File slack
  Files are created in varying lengths depending on their contents. Computers store files in fixed length blocks of data called clusters. Rarely do file sizes exactly match the size of one or multiple clusters perfectly. The data storage space that exists from the end of the file to the end of the last cluster assigned to the file is called "file slack" [20].
- Browser and memory cache
  Cache is a section of a computer's memory which retains recently accessed data in order to speed up repeated access to the same data. Browsers use cache memory to load Web pages more quickly. A network caching device stores

copies of frequently requested files so local users can access them more quickly than going all the way to the origin server.

- Telephones/Answering machines,
- Copiers,
- Video game systems,
- GPS devices,
- Digital cameras,
- Floppies,
- ZIP disks,
- Flash memory cards,
- Unallocated storage space
  When files are erased or deleted in DOS, Windows, Windows 95, Windows 98 and Windows NT, the content of the file is not actually erased. Data from the deleted file remains behind in an area called unallocated storage space[21].
- Backup tapes,
- Compact disks,
- DVDs,
- Micro drives,
- DAT,
- Memory sticks

and many more.

2.5 Definition

Digital forensic Science as defined at DFRWS 2001[1]:

The use of scientifically derived and proven methods toward the preservation, collection, validation, identification, analysis, interpretation, documentation and presentation of digital evidence derived from digital sources for the purpose of facilitating or furthering the reconstruction of events found to be criminal, or helping to anticipate unauthorized actions shown to be disruptive to planned operations.

[1] DFRWS stands for Digital Forensic Research Workshop

As we have seen there are numerous sources of digital evidences. The use of digital devices in white collared crimes makes it very important for all the evidences to be seized. The next Chapter gives a detailed overview of the forensics investigation process, the different phases involved in the investigation, the hardware and software tools used and the rules to be followed during investigation.

Chapter 3

Digital Forensics Investigation Process

In this Chapter we present a detailed explanation of the steps involved in the digital investigation process, the hardware and software tools available for the investigation, and the rules of investigation. Finally we discuss the limitations encountered during the investigation process, in spite of the available resources, due to the variety of digital sources that can act as digital evidences, and different behaviors of softwares on different operating systems.

3.1 Overview

There is a basic, inherent process to computer forensics which can be outlined as the following:

- Identification
- Acquisition
- Data recovery
- Analysis
- Presentation
- Documenting and reporting

Each of the above phases has a set of standard procedures and tools being used.

In [1], Rodney McKemmish makes an analysis of the different aspects of forensic computing, and the steps that a forensic examiner must follow.

3.2 Identification

Identification deals with intelligence gathering. In this step, the examiner identifies all the digital devices that can act as source of evidence such as mobile phones, electronic organizers, floppy disks, hard drive, etc. The examiner must be able to determine where and how the evidence was stored. This will be very important for presenting in Court.

3.2.1 Limitations

The process of forensics investigation requires the law enforcement personnel, dealing with it, to be trained in electronic devices, their hardware and software. Even the most successful forensics training can only give common sense about computers and other digital devices. Considering the variety of digital devices being a potential source for forensics evidence, it is hard for a forensics investigator to tell which device can have what data. For example, an innocuous looking Xbox console could be running a Linux FTP Server inside it. Identification of digital evidences could be a cumbersome step. A knowledge base of lessons could keep the examiner more alarmed about such cases.

3.3 Acquisition

The acquisition phase saves the state of a digital system so that it can be later analyzed. This entails the recording of the physical scene and duplicate digital evidence using standardized and accepted procedures. The preservation of digital evidence is the critical

element in the forensic computing because it will be used in court. Therefore is it very important not to make any kind of modification. However, if changes were unavoidable the examiners would have to try to make the least number of changes as possible and when showing the modified evidence in court, all kinds of alteration would have to be explained in detail; changes in data or physical changes. The validity of the evidence depends on the explanation that the examiners give. This digital data includes both snapshot and live datasets as needed. *A snapshot is an image taken of the display screen by a program or by using a camera and stored in a file for later use. Dataset means any resource that is a collection of pieces of data.* Databases, data in spreadsheets or collections of statistics are examples of dataset. Live dataset refers to a dataset found at the crime scene. All snapshot data sources are seized or forensically imaged and live data is acquired in a notarized manner. *Imaging is the term given to creating a physical sector copy of a disk and compressing this image in the form of a file.* During the acquisition phase, at a minimum, the allocated and unallocated areas of a hard disk are copied, which is commonly called an image. This process is referred to as “Imaging”.

This image file can then be stored on dissimilar media for archiving or later restoration. Actions taken to secure and collect digital evidence should not affect the integrity of that evidence. Examination is best conducted on a copy of the original evidence.

3.4 Data Recovery

Forensic data recovery is the science of recovering information from a computer that may have been deleted or otherwise damaged or hidden. Discussed below are two different types of data recovery mechanisms, physical and logical. The physical extraction phase

identifies and recovers data across the entire physical drive without regard to file system. The logical extraction phase identifies and recovers files and data based on the installed operating system(s), file system(s), and/or application(s).

3.4.1 Physical extraction

During this stage the extraction of the data from the drive occurs at the physical level regardless of file systems present on the drive. This may include the following methods:

- Performing a keyword search across the physical drive to extract data.
- File carving utilities processed across the physical drive to recover and extract useable files and data. *File carving utility is the process of recovering files from unallocated file space.*
- Examining the partition structure to identify the file systems present.

3.4.2 Logical extraction

During this stage the extraction of the data from the drive is based on the file system(s) present on the drive and may include data from such areas as files, deleted files, file slack, and unallocated file space. Steps may include:

- Extraction of the file system information to reveal characteristics such as directory structure, file attributes, file names, date and time stamps, file size, and file location.
- Data reduction to identify and eliminate known files through the comparison of calculated hash values to authenticated hash values.

- Extraction of files pertinent to the examination. Methods to accomplish this may be based on file name and extension, file header, file content, and location on the drive.
- Recovery of deleted files.
- Extraction of password-protected, encrypted, and compressed data.
- Extraction of file slack.
- Extraction of the unallocated space.

3.4.3 Limitations

Every new investigation process can have new hardware and software involved. Repeating steps performed in the past investigations cases, might hardly be useful. With a different device, a different Operating System, and a different version, the difficulty of the investigation problem may increase threefold. Sometimes, there is no explanation for the way softwares behave. A program installed and executed at one instance of time over a given combination of hardware device and Operating System, may not work on a similar combination, at some other instance of time, due to conflict in versions used. For example, an examiner acquired a zipped file as one of the evidence sources. It was password protected using the latest version of WinZip. This version of WinZip used a different password encryption scheme than the older versions. Available commercial and open source Password crackers could not break the encryption on the latest WinZip version. These password crackers worked successfully on the older version of WinZip. But when the examiner tried to unzip the zipped file with any other older versions of WinZip, even with the right password, the file would not open. A situation like this can

lead to a dead end, and the files in the zipped file can never be recovered. The only solution to it is, upon knowing the password, open the file using the same version of WinZip that was used to zip it. Issues like these, if not documented, can waste a lot of time in trying to reach the solution. There can be some other forensics investigator, who could be facing the same problem. A small help like this could be invaluable to the forensics community. Hence it is important that we document such results and experience.

3.5 Analysis

Analysis refers to the interpretation of the recovered data and putting it in a logical and useful format. Some examples of analysis that may be performed include timeframe analysis, data hiding analysis, application and file analysis, and ownership and possession analysis.

3.5.1 Timeframe analysis

Timeframe analysis can be useful in determining when events occurred on a computer system, which can be used as a part of associating usage of the computer to an individual(s) at the time the events occurred. Two methods that can be used are:

- Reviewing the time and date stamps contained in the file system metadata (e.g., the time the file was last modified, last accessed or created) to link files of interest to the timeframes relevant to the investigation.
- Reviewing system and application logs that may be present. These may include error logs, installation logs, connection logs, security logs, etc. For example,

examination of a security log may indicate when a user name/password combination was used to log into a system.

3.5.2 Data hiding analysis

Data can be concealed on a computer system. Data hiding analysis can be useful in detecting and recovering such data. Methods that can be used include:

- Correlating the file headers to the corresponding file extensions to identify any mismatches. Presence of mismatches may indicate that the user intentionally hid data.
- Gaining access to all password-protected, encrypted, and compressed files, which may indicate an attempt to conceal the data from unauthorized users.
- Steganography. *Steganography is the art and science of hiding information by embedding messages within other messages.* Steganography works by replacing bits of useless or unused data in regular computer files (such as graphics, sound, text, HTML, or even floppy disks) with bits of other, invisible information. This hidden information can be plain text, cipher text, or even images.

3.5.3 Application and file analysis

Many programs and files identified may contain information relevant to the investigation and provide insight into the capability of the system and the knowledge of the user. Results of this analysis may indicate additional steps that need to be taken in the extraction and analysis processes. Some examples include:

- Reviewing file names for relevance and patterns.

- Examining file content.
- Identifying the number and type of operating system(s).
- Correlating the files to the installed applications.
- Considering relationships between files. For example, correlating internet history to cache files and e-mail files to e-mail attachments.
- Identifying unknown file types to determine their value to the investigation.
- Examining the users' default storage location(s) for applications and the file structure of the drive to determine if files have been stored in their default or alternate location(s).
- Examining user-configuration settings.
- Analyzing file metadata, the content of the user-created file containing data additional to that presented to the user, typically viewed through the application that created it. For example, files created with word processing applications may include authorship, time last edited, number of times edited, and where they were printed or saved.

3.5.4 Ownership and possession analysis

In some instances it may be essential to identify the individual(s) who created, modified, or accessed a file. It may also be important to determine ownership and knowledgeable possession of the questioned data. Elements of knowledgeable possession may be based on the following factors:

- Placing the subject at the computer at a particular date and time may help determine ownership and possession (*timeframe analysis*).

- Files of interest may be located in non-default locations (e.g., user-created directory named "child porn") (*application and file analysis*).
- The file name itself may be of evidentiary value and also may indicate the contents of the file (*application and file analysis*).
- Hidden data may indicate a deliberate attempt to avoid detection (*hidden data analysis*).
- If the passwords needed to gain access to encrypted and password-protected files are recovered, the passwords themselves may indicate possession or ownership (*hidden data analysis*).
- Contents of a file may indicate ownership or possession by containing information specific to a user (*application and file analysis*).

3.5.5 Limitations

During the investigation, some configurations or devices occur infrequently enough that the solution, though known and previously used, is not clearly remembered and needs to be researched. Dealing with such issues can take days and weeks, following up dead ends and researching the technology.

For instance, one of the examiners was asked to image a hard drive and provide the image file for analysis. He found that the hard drive exhibited some partition table errors that rendered it absolutely unavailable in the DOS or Windows environment. Ordinary tools for partition table examination could not identify the partition type, but the data area of the drive clearly contained a Windows operating system and typical applications for a home computer. Consequently, the examiner decided to make an image file using the

Linux dd command. Unfortunately, the Linux dd command has literally dozens of combinations of command line switches. Luckily, someone had already researched the use of dd as a forensic tool, and posted a page (http://www.crazytrain.com/dd.html) providing exactly the information needed to put dd to use as a forensics tool. This lesson literally saved the investigator dozens of hours of research and trial and error. Thus it is very important that there exist a knowledge base that can contain information and experience of other examiners.

3.6 Presentation

The presentation of digital evidence is the part of the forensic computer that is more related to the law. All the work described before would have no meaning if the information obtained from the electronic evidence could not be used in a trial. That is why the manner of presenting evidence is very important. Presentation will involve creating a final report to present the digital evidence obtained and supporting a liturgical process if needed. This report must be a self contained, self explanatory written document in which all relevant actions taken during the identification, acquisition and analysis phases are reflected. Digital evidence should be presented along with all the needed detail necessary for an independent examiner to reproduce and validate such piece of evidence. That has to be done by qualified examiners who can give understandable explanations about the technological methods used to analyze it.

It has to be considered that it is possible to find people in court that do not have any knowledge about technology, but do know about the law. This is the reason why all

investigation and analysis processes within forensic computing, like in other areas of information technology, should be done legally and carefully.

Even if the results and information obtained are correct and imply the real criminals, they would be invalid in court if the legal forms would not have been respected.

3.7 Documenting and reporting

The examiner is responsible for completely and accurately reporting his or her findings and the results of the analysis of the digital evidence examination. Documentation is an ongoing process throughout the examination. It is important to accurately record the steps taken during the investigation process.

3.8 Tools used in Forensics investigation process

3.8.1 Hardware Tools

In a digital forensics computing examination, it is important to have efficient tools for the analysis, both for software and hardware. Some of the hardware tools used by forensics investigators are:

- Image Master [2]

  Image Master can be used as standalone tool for effective image processing.

- DRAC Series Computers

  They are engineered for investigation and recovery of digital artifacts.

- FRED (forensic Recovery of Evidence Device)

  FRED systems are optimized for stationary laboratory acquisition and analysis.

The hard drive(s) from the suspect system are plugged into FRED to acquire the digital data.

- VOOM ShadowDrive

  It enables forensics investigators to boot and view a suspect's system on site, without threat of altering the evidence on the boot drive.

- The Mobile forensic platform

  The Mobile forensic platform [3] (MFP) is a stand-alone machine, connected to the same local subnet as the machine to be investigated, allowing for high-speed transfer of data. The investigator, or an administrator, connects to the MFP through a secured connection (either through the Internet via a VPN[2] or a phone line), encrypting all data transferred between the machines, such as via HTTPS.[3]

3.8.2 Software Tools

Before analyzing digital evidence, it is important that the investigator starts with a good image of the media that he wants to investigate. The reason is that the examiner must not modify the data during the seizure [4]. Some of the standard forensic software tools used by examiners during recovery and analysis of data are:

[2] VPN stands for Virtual parallel network
[3] HTTPS stands for Hyper Text Transport Protocol Secure

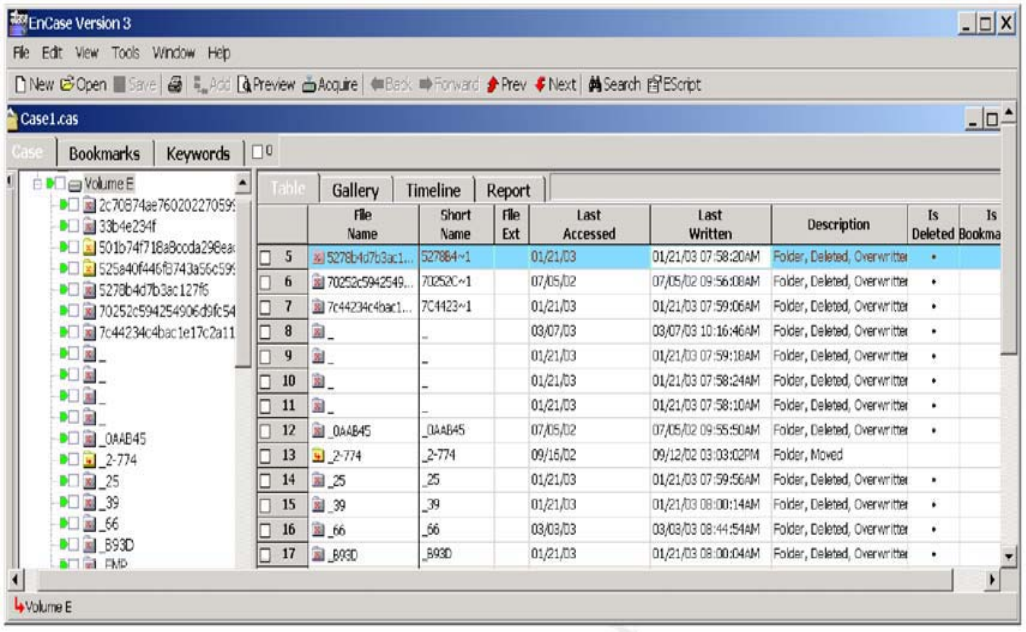


Figure 3.1 Image of EnCase Version 3

- Data dumper (dd)

  dd is a freely available utility for Unix systems that can make exact copies of disks that are suitable for forensic analysis. It is a command line tool and requires a sound knowledge of the command syntax to be used properly.

- EnCase

  EnCase software allows investigators to view computer drive contents including files, operating system artifacts, file system artifacts, and deleted files or file fragments located in file slack or unallocated space. It mounts the copied bit-stream images as read-only virtual drives. EnCase is most used when the examiners are using Windows systems as the investigation platform.

- Coroner's Toolkit

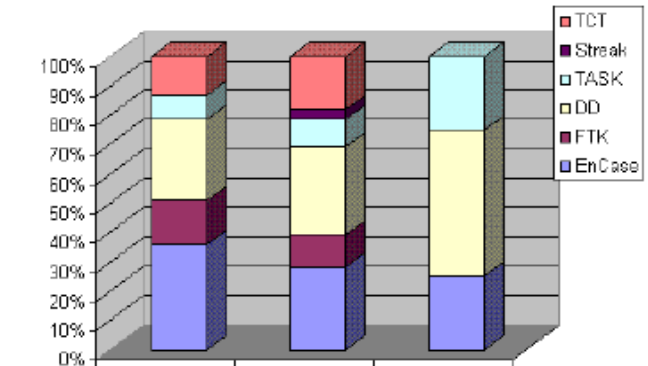
  If the platform used is Unix, the most used software by examiners is the

Coroner's Toolkit [6]. This software package is an entire suite of tools used for examining forensic evidence. Examples of programs in The Coroner's Toolkit include the "mactime" program which is used for investigating the MAC (Manipulation, Access, Creation) times associated with every file, programs that are used in recovering unallocated clusters of raw data, etc.

- FTK

  FTK is another software tool available for computer forensic examination. FTK provides features like file filtering, search functionality, performing e-mail analysis, advance searches for JPEG images and internet text, recovering deleted files and partitions, decrypting protected storage data, viewing registry files, etc.

In Figure 3.2 [5] we can see a comparison of these tools:



	Government agency	Private company	Student
TCT	8	21	
Streak		4	
TASK	5	11	1
DD	17	35	2
FTK	9	13	
EnCase	22	33	1

Figure 3.2 Usual software tools in forensics computing [6]

3.8.3 Limitations

In spite of the available hardware tools and software investigative suites, an examiner every now and then experiences problems that cannot be straightforwardly solved using these tools. For example, an employee of a company reports a problem on his machine. The administrator reinstalls Windows on the machine. Reinstallation wipes out the Outlook file header. Emails are encrypted using Outlook's default encryption cipher. None of the existing commercial tools described above could recover the emails, because the outlook file header was lost. A simple solution of this problem was to write software that would use a simple substitution table to recover the headers of the emails. The key point here was to recognize the fact that a simple substitution table could recover the body of the emails. A documented lesson like this can be so important to the forensics community. What seemed to be an impossible recovery mechanism was just a matter of simple substitution. Had this knowledge been documented correctly, this could be of use to so many investigators.

3.9 Rules of Forensics Computing

There exist different kinds of rules in forensic computing. Some of them are related to the correct awareness for the investigation, and other rules talk about the steps that the forensic examiners must follow if they want to proceed according to the law and avoid problems when presenting the results in Court.

3.9.1 General Rules

As McKemmish explains in [1], we should not forget that the final goal of the forensic computing is to use the evidence analyses in a Court, so it is very important to follow, all the time, the rules of the governing laws. So, considering this idea, he defines four rules for forensic computing:

Rule 1- Minimal handling of the original.

> "*The application of forensics investigation during the examination of original data shall be kept to an absolute minimum*"
>
> This is the most important rule of forensic computing. As the electronic evidence will be used in Court, it must be shown with the minimal alteration possible. That is why, for showing the results of the analysis of the real "objects" you have to make an analysis of a copy of the original evidence.

Rule 2- Account for any change

> "*Where changes occur during a forensic examination, the nature, extent and reason for such changes should be properly documented*"
>
> Sometimes it is impossible to avoid alteration in the original. When the examiner is in this situation, he must have a fully understanding of the kind of the alteration. The examiner must explain with all kinds of details why the evidence was changed, which change was made, which consequences the change produces in the evidence and in general in all the analysis etc. Perhaps this issue is not a problem when the examiner is making the analysis, but can be a big problem during judicial proceedings. If there exists any kind of doubt in the explanation of the evidence, it could be challenged even if it is important for the investigation.

But sometimes it is necessary to alter the evidence, for example if the examiner is forced to change a logical flag like an access bit or an entire string of binary data for the access. In this kind of situations, the examiner must explain that this kind of change does not change the contents of the evidence, and it is only in order to access to the information.

Rule 3- Comply with the rules of evidence

"*The application or development of forensic tools and techniques should be undertaken with regard to the relevant rules of evidence*".

This point explains that in forensic computing the application of tools and techniques must not change the evidence.

Rule 4- Do not exceed your knowledge

"*The forensic computing specialist should not undertake an examination that is beyond their current level of knowledge and skill*".

It is very important that the examiner is aware of the limits of their knowledge and never exceed it. That is why if in an investigation the examiner continues with the examination in the hope that all goes well and without skilled personnel, it is very dangerous because the examiner must be able to describe correctly the methods and the process used during the examination. If it is not possible to explain in a clear form these issues, it means that the credibility of the evidence and the examiner is in doubt and it has consequences in the Court. A correct forensic investigation must be led by qualified examiners who receive a competent training in this field because the results of their investigation can change the results in a trial.

3.9.2 Rules in the investigation procedure and seizure

These general rules as shown above are steps that forensics computing examiners must follow in a rigorous form. A few of these steps are given in federal guidelines for searching and seizing computers [7].

1. Have a legal right to seize and investigate the suspect computer. Have appropriate approval, search warrant, subpoenas etc.
2. Protect the crime scene- The scene should be documented in great detail. Photograph the computer from all angles and the surrounding area. In addition to photography, diagram the computer configuration on paper and by labeling which cables are attached and what they attach to.
3. Kill the computer's power source - Do not shut the computer down through the normal shutdown process. There could be cleanup procedures implemented to delete data. Unplug the computer from the power source. This should be a direct source of power such as a wall outlet, power strip, or UPS if one is present.
4. Disconnect the hard drive – You should never use the suspect computer's hard drive to boot from or it operating system to perform investigative tasks. You do not know what type of cleanup procedures are waiting in the boot process. Disconnect the hard drive and boot from floppy disk (the BIOS may need to be modified to allow boot from a floppy).
5. Make a bit stream image of all disk space –You should make a bit stream image of the suspect hard drive before anything else.
6. Examine free space and file slack, which can contain deleted information and/or hidden data. Free space comes from the available sectors that have not been

written to or have been made available from hidden files. File slack is the area of space in an occupied cluster that spans the point where file data ends to the end of the cluster. This area is sometimes used to hide data or where deleted data may remain.

7. Be aware of swap files that may contain valuable data. Some systems have files that are used to cache information between memory and the hard drive; these files are known as swap files.
8. Mathematically authenticate the data – use a hash algorithm to generate a numeric expression and compare this to the same hash algorithm on the data that was backed up. This is used as proof that the file has not changed.
9. Discover all files – Use disk utilities such as undelete to recover as much of the deleted data as possible. When recovering data with the undelete utility, you should avoid using the real first character. It is recommended to use a common character that is not typical to any filenames. This way you can identify what files were recovered by being undeleted: In addition, use utilities to search the disk for hidden files.
10. Search the contents of the hard drive for any incriminating evidence. Make a list of key words that pertain to the investigation. This could help narrow down some of the data that is pertinent.
11. Analyze all of the relevant data that was found from your search.
12. Document all processes in detail as they are being performed. From the beginning notification of possible illegal activity to the very end of the investigation.

13. Prepare to make and defend your accusations in a Court of law. You should be confident in your accusations and your knowledge of computer operations.

Chapter 4

Related Work

In this thesis we design and create a knowledge base, a digital forensics repository, to support the sharing of experiences about the forensics investigation process. It offers capabilities such as submission of lessons, online search and retrieval which will provide a means of querying into an ever increasing knowledge base. Amongst the available resources in building such a repository, there is a paper on "A Lessons Learned Repository for Computer forensics" [12] that discusses the layout and classification and other policies as required by the forensics community. The paper serves as a guideline in building this repository of "Lessons Learned".

Here we briefly describe the various policies discussed in the paper [12] and our implementation of these policies and further improvements on it.

Who can add a lesson?

The Paper's proposal:

The "contributor policy" could be as loose as allowing anyone with access to an internet connection and a web browser to add lessons at will. On the other hand, one could imagine a much more restrictive policy in which individual users are "certified" as competent to add a lesson.

Our Implementation:

The prototype repository has three levels of access control.

1. Privilege of posting lesson without any supervision
2. Privilege of posting lesson only with supervision.
3. No privilege of posting lesson.

Who can read a lesson?

The Paper's proposal:

Under the most restrictive implementation of the "user policy", only representatives of bona fide law enforcement organizations would be able to access the content of the repository. This would make the operation of the repository extremely expensive, since every user would have to be evaluated.

Our Implementation:

There is no restriction on who can read the lessons. All users of our system can view all lessons.

How much does a Contributor need to tell about themselves?

The Paper's proposal:

The least restrictive implementation of this policy is simply allowing contributors to remain totally anonymous. The alternative to total anonymity is to require contributors to associate their name, affiliation and even e-mail address with a lesson.

Our Implementation:

We choose the least restrictive implementation of this policy, where in contributors can remain totally anonymous.

How to ensure the validity of a lesson?

The Paper's proposal:

1. Prior to publishing a lesson, it is reviewed by a panel of peers who agree that the lesson will work.
2. Users are encouraged to rate the degree to which they trust the lessons.

Our Implementation:

We allow the users to rate a lesson. Users can rate lessons according to their discretion, depending on whether or not and how useful the lesson was to them. Depending on the lesson rating, we choose the lesson of the day. The key idea behind using this policy was that it is cost-effective and easy to implement.

Contributing to the Repository:

The paper's Proposal:

A generalized 2-3 line summary of the lesson that concisely represents the lesson so the user can tell if it is applicable to their needs without reading the entire lesson.

- A discussion of the details relating to this lesson. It is expected that this section convey the "wisdom" to be found in the lesson. While this should not be a voluminous tome, some detail should be conveyed so the wisdom can be replicated in another context.

- A series of "index categories" intended to aid users in locating applicable lessons. These indexes consist of beneficiary, phase, classification and technology. The index information is selected from a pre-defined list of choices if possible to avoid “index sprawl” and enforce consistency in contributor indexing.
- Optional electronic mail/name/agency of the contributor.

Our Implementation:

Our implementation of the prototype follows the paper to some extent, and introduces a new category of keywords for each lesson. In order to make the contribution process less tedious for the users, we categorize data to be submitted in a manner that is easy and flexible. This is how we classify the data to be contributed:

- Firstly, we divide the data based on the “phases of investigation” where the user might have experienced problems. An investigator might not have experienced difficulty at every step in the investigation process. For instance, an investigator might be successful in recovering all the data, from the available evidences, but he might have problems during the analysis stage. So we let the user select from the following “phases of investigation”:
  - **Imaging**
  - **Data recovery**
  - **Data analysis**
- Each of these phases is associated with a set of tools. For example, to make an image or copy of the evidence, users may use the dd command or may use some popular investigative suite like FTK Imager, depending upon the Operating

System of the target machine. So the user selects from a series of index categories such as

- **Investigation suites**

  For the imaging phase, along with **dd**, the following standard and commonly used investigation suites are listed:

  - **FTK imager**
  - **Ghost**
  - **Encase**

- For data recovery and data analysis phases other investigation Suites are listed:

  - **FTK**
  - **iLook**
  - **SMART**
  - **Encase**
  - **Coroner's Tool Kit**

- **Target devices**

  The target devices are a set of digital devices which can be treated as evidence. These target devices are:

  - **Cell Phone**
  - **PDA**
  - **Desktop**
  - **Laptop**
  - **Network**

- **Operating System of the target machine**

  A list of Operating Systems is displayed:

  - **Windows**
  - **Linux**
  - **Unix**
  - **Palm OS**
  - **Mach**

- Users may add any other index that is not defined by selecting the "**Other"** option. This is just to provide the required flexibility.
- Then a few words that define the most appropriate **title** for the lesson
- The **problem** encountered during that Phase
- The procedure used to tackle this problem. This may be the actual/best **solution** of this problem or the one adopted by the user to get around with this difficulty.
- A few **keywords** that will help in searching the lessons more efficiently.
- **Submit report**

  Optionally, the User may also upload a **text, word, power point or html** file containing a summary or description of the problem they encountered and the solution to it. **Keywords** are also required to be associated with the file uploaded.

What are Keywords and why should they be used?

- Keywords are words that would be most appropriate to search for the lesson.
- It defines the specialty of the lesson, not the generality.
- Keywords are useful tools in searching for the lesson.
- Keywords help in reducing noise while searching.

Searching the lessons

The Paper's proposal:

Several interaction approaches are possible, including index searches, full-text, "in-string" searches and simply allowing users to browse through the individual lessons. Additionally, when using searches, providing some form of "matching score" so Users

can tell how well a lesson matches their criteria, so lessons that just match one index out of several are flagged as being “less of a match” than lessons containing every search term.

Our Implementation:

Lessons are stored in Database using two Tables. The Table ‘LLearned’ consists of the well-structured lesson as submitted by the user. The table ‘Upload’ contains the **text, word, power point or html** files submitted. For searching the lessons the User can select from the indexed categories of investigative suites, target device and operating system, and enter their search queries. The keywords and title of the lessons, stored in the database, are searched using these indexes and search query and appropriate matches are returned. The use of keywords leads in less number of false matches and more correct results. The user is free to select any or none of the given indexes. While searching reports too, only title and keywords are searched, the entire text of the report is not searched, thus generating less noise.

Other Features

Other than the above mentioned features and policies our Repository implements the following features:

- Book marking lessons

  Users may want to bookmark lessons of their choice for later use or reference. For now our implementation does not have a limit on the bookmarks, but in the future, we may impose and limit and allow users to edit their bookmarks.

- RSS Feeds available for lesson of the day

- Posting Questions to other Users

  Users can get answers to Questions that are not available in the repository.

- Searching the available resources on the Web

  The best resource available for most investigators is online tutorials. We allow Users to search existing Forums such as http://www.forensicsfocus.com and Yahoo Groups and incorporate their search results on our Webpage.

- Creating lessons from available resources

  When the Users finds a tutorial or lesson or article on the Web useful and would like to submit that article to the repository, then based on his privilege levels, he is allowed to save that article in the database.

Related work

There is a lot of literature on Knowledge-based systems and Content management systems. For our Repository of lessons Learned from forensics computing, we looked at the following works.

KnowledgeTree™ [9] is an Open Source document management system. The product provides a content repository, workflow and routing of content, content publication and content metrics definition and analysis. This product allows

- Version control
- Full-text search of common file formats (MS Word, MS Excel, PDF, TXT, HTML)
- Archiving according to expiry date, expiry time period or utilization for enhanced speed

and other features.

The COTS lessons learned repository [10] aims at disseminating valuable knowledge and experience between practitioners involved in COTS-based development. The prototype is at [11]. The lessons are described in the repository by a set of attributes, the most important being the ones describing the context in which the lesson was learned (type of system, type of company, number and type of COTS). Other attributes refer to type of data, recommended audience, relevant life cycle phase, etc. Most of the attributes were chosen based on a bottom-up effort to differentiate the lessons learned in the initial repository, but others were added simply because they seemed to reflect issues of interest to potential practitioners (e.g. impact on cost, quality and schedule).

The interface to the repository supports search and retrieval based on text searches over all attributes. Links to the original source of each lesson are also provided.

The model we required for the forensics repository required the data to be classified in a manner that would organize it based upon its utilization in the forensics investigation process. An officer working on some case, might need to find something about how to image a file using dd. And so if he looked up information on the web, he might be forced to read through a lot of tutorials that might not be even relevant to what he is doing. So we needed a classification that was unique to the digital forensics computing process.

Chapter 5

Technology Overview

5.1 Basic Technologies

For building this Web application, we use the .NET Framework. Web pages are built in Active Server Pages (ASP.NET). C# is the language used.

The .NET Framework

The .NET Framework consists of two main parts [16]: the **common language runtime** (CLR) and a unified, hierarchical **class library** that includes **Active Server Pages** (ASP.NET), an environment for building client applications (Windows Forms), and a loosely-coupled data access subsystem (ADO.NET). The Microsoft .NET Framework is a multi-language platform for building, deploying, and running Web Services and applications.

Common Language Runtime

The common language runtime (CLR) is responsible for run-time services such as language integration, security enforcement, and memory, process, and thread management. In addition, the CLR has a role at development time when features such as life-cycle management, strong type naming, cross-language exception handling, and dynamic binding reduce the amount of code that a developer must write to turn business logic into a reusable component.

Figure 5.1 The .NET Framework Architecture

Class Libraries

Base classes provide standard functionality such as input/output, string manipulation, security management, network communications, thread management, text management, and user interface design features.

The ADO.NET classes enable developers to interact with data accessed in the form of XML through the OLE DB, ODBC, Oracle, and SQL Server interfaces. XML classes enable XML manipulation, searching, and translations. The ASP.NET classes support the development of Web-based applications and Web services. The Windows Forms classes support the development of desktop-based smart client applications.

Together, the class libraries provide a common, consistent development interface across all languages supported by the .NET Framework.

Visual Studio .NET

Visual Studio .NET is a complete set of development tools for building ASP Web applications, XML Web services, desktop applications, and mobile applications.

ASP.NET Web Application

ASP.NET is a compiled, .NET-based environment; you can author applications in any .NET compatible language, including Visual Basic .NET, C#, and JScript .NET. Web Forms is an ASP.NET feature that you can use to create the user interface for your Web applications. The user interface programming is divided into two distinct pieces: the visual component and the logic. The visual element is referred to as the Web Forms page. The page consists of a file containing static HTML, or ASP.NET server controls, or both simultaneously. The logic for the Web Forms page consists of code that you create to interact with the form. The programming logic resides in a separate file from the user interface file. This file is referred to as the "code-behind" file.

Session Management in ASP.NET

HTTP, the underlying transport of the Web, is a memory-less protocol. Every time a client requests an application, HTTP has no idea of the caller's identity. It simply forwards the request to the Web server.

Both JSP and ASP.NET use the concept of sessions and Session objects to store data unique to a particular client while that client is connected to a Web application. When a session begins, the requesting browser is given unique piece of information, or "ticket," that is presented by the browser on subsequent visits to identify the user. The Web application can then, for example, customize the settings for that user when she visits, since it can find her personal preferences using the information stored in the Session object referenced by the ticket.

The session state has no correspondence to any of the logical entities that make up the HTTP protocol and specification. The session is an abstraction layer built by server-side development environments such classic ASP and ASP.NET.

Lifetime of a Session:

An important point about ASP.NET session management is that the life of a session state object begins only when the first item is added to the in-memory dictionary. Only after executing code like in the following snippet, can an ASP.NET session be considered started.

```
Session["MySlot"] = "Some data";
```

The Session dictionary generically contains Object types; to read data back, you need to cast the returned values to a more specific type.

```
string data = (string) Session["MySlot"];
```

A script can end a session programmatically by calling the Abandon method of the Session object. When a user completes an application and a session is no longer needed, the script can simply call Session.Abandon to end the session and free the server resources used by that session. A session can also end if the user does not make any HTTP requests to the ASP application for a specified time-out period. This period defaults to 20 minutes, but can be adjusted by setting the Timeout property of the Session object. If a user begins a session, but stops making requests to the Web application, ASP will time out the session after the specified idle period expires.

C#:

C# is an elegant, simple, type-safe, object-oriented language that allows enterprise programmers to build a breadth of applications.

C# also gives you the capability to build durable system-level components by virtue of the following features:

- Full COM/Platform support for existing code integration.
- Robustness through garbage collection and type safety.
- Security provided through intrinsic code trust mechanisms.
- Full support of extensible metadata concepts.

Google API

We have integrated the Google Web API [17] into our web-application for searching the available resources online. With the Google Web APIs service, we can query more than 8 billion web pages and use the search results to create lessons. Google Web APIs are implemented as a web service. The service supports several SOAP methods.

The web-application connects remotely to the Google Web APIs service and queries its methods.

RSS 2.0 Feeds

RSS stands for “Really Simple Syndication”. RSS is a XML format designed for sharing headlines and other Web content. An RSS feed is a regularly updated XML document that contains metadata about a news source and the content in it. RSS defines an XML

grammar for sharing news. Each RSS text file contains both static information about the site, plus dynamic information about the news headlines, all surrounded by matching start and end tags. Minimally an RSS feed consists of a channel that represents the news source, which has a title, link, and description that describe the news source.
Additionally, an RSS feed typically contains one or more item elements that represent individual news items, each of which should have a title, link, or description.
RSS-aware programs are called news aggregators. A news aggregator can help you find, organize and view RSS feeds. Our Repository application provides an infrastructure for generating RSS feeds for “lesson of the day”.

5.2 Database: SQL Server 2000

Microsoft SQL Server is a relational database management and analysis system for e-commerce, line-of-business, and data warehousing solutions.
SQL Server 2000 includes

- support for XML and HTTP
- Performance and availability features to partition load and ensure uptime and advanced management and tuning functionality to automate routine tasks.
- SQL Server 2000 offers an enhanced full-text search service that allows you to:
    1. **Update indexes in the background:** Populating or updating an index does not have to interfere with other tasks. Full-text index updates can be scheduled in the background using the Full-text Indexing wizard, SQL Server Enterprise Manager, or the SQL Server Agent job scheduler.

2. **Choose among three methods of maintaining a full-text index:** Depending on your data and resources, you can choose among the full rebuild, the timestamp-based incremental rebuild, and the change tracking methods to maintain your full-text indexes. The full rebuild method involves rescanning all rows. The timestamp-based incremental rebuild method only rescans those rows that have changed since the last rebuild (full or incremental) of the index. With the change tracking method, SQL Server maintains a list of all changes to the indexed data and you can use this list to update the full-text index. We use the **change tracking method**.
3. The Full-Text Search feature of Microsoft SQL Server 2000 allows you to perform fast and flexible queries against indexes built on unstructured text data. A common use of Full-Text Search is that of the search engine for web sites.

5.3 Multi-Tier IIS Applications

In the implementation of this Prototype Repository we use the n-tier architecture. In this model, processing is distributed between the client and the server, and business logic is captured in a middle tier. Most systems perform the following three main tasks, which correspond to three tiers, or layers, of the n-tier model.

The following table describes the three tiers as discusses in [8]: The three-tier architecture isolates each major piece of functionality, so that the presentation layer is independent of the processing rules and business logic, which in turn is separate from the

data. This model requires much more analysis and design up front, but greatly reduces maintenance costs and increases functional flexibility in the long run.

Task	Tier	Description
Presentation Layer	Tier 1	This layer comprises the entire user experience. Not only does this layer provide a graphical user interface (GUI) so that users can interact with the application, input data, and view the results of requests, it also manages the manipulation and formatting of data once the client receives it back from the server. In Web applications, a Web browser performs the tasks of this layer.
Business logic	Tier 2	Between the interface and data services layers, is the domain of the distributed application developer. Business logic, which involves the rules that govern application processing, connects the user in tier 1 with the data in tier 3. The functions that the rules govern closely mimic everyday business tasks, and can be a single task or a series of tasks. The code in this tier must be developed with security in mind because user input crosses trusted boundaries.
Database services	Tier 3	Database services are provided by a structured (SQL, Oracle database, XML database) or unstructured (Microsoft® Exchange, Microsoft® Message Queuing) data store, which manages and provides access to the data contained within. A single application may enlist the services

		of one or more data stores.

The following illustration Figure 5.2 shows the Microsoft technologies [8] that service the various tiers in the new system architecture.

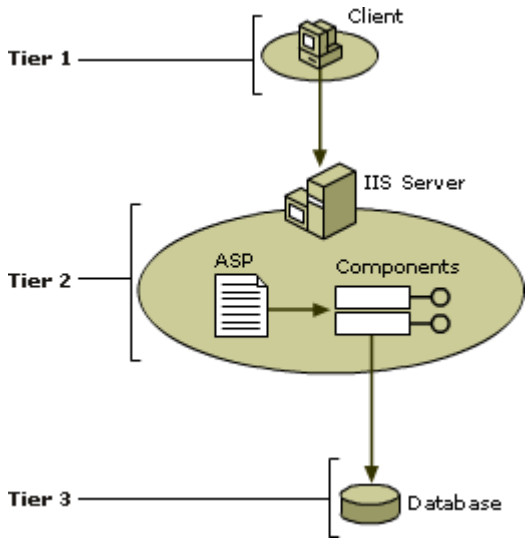


Figure 5.2 3-Tier Technology Architecture

Chapter 6

Prototype Forensics Repository implementation

6.1 Technology Architecture

The prototype has the following multi tier technology architecture as shown in Figure 6.1 [18]. Figure 6.1 shows where the components are deployed in the architecture and which tier sustains each component such as the Database, ASP.NET Web Forms and IIS Server.

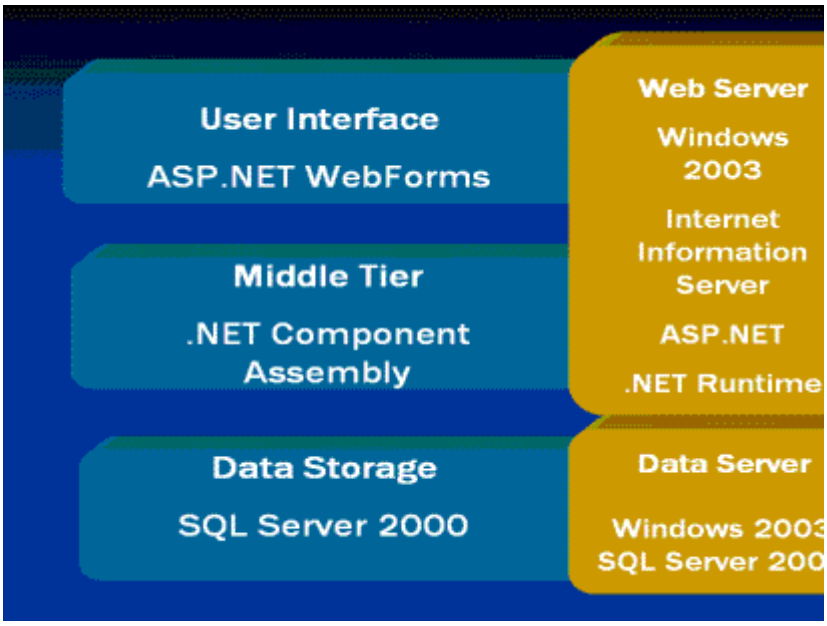


Figure 6.1 Physical architecture mapped against 3-tier architecture

6.2 Functional Architecture

Figure 6.2 shows the various Web forms deployed in the application. It presents a comprehensive view of interaction of all the web pages in the application.

When the User logs in, the privilege level associated with the User is retrieved from the Database. Depending upon the Privilege level, the User can either post lessons with or without supervision or not post at all.

A new User would require registering to view any lessons. The Home page shows the most recent questions posted and the solutions if any, the lesson of the Day and the Bookmarks the User added. A User can Find lessons, Search the Web, create lessons from the resources available online, add bookmarks, rate lessons as per their discretion.

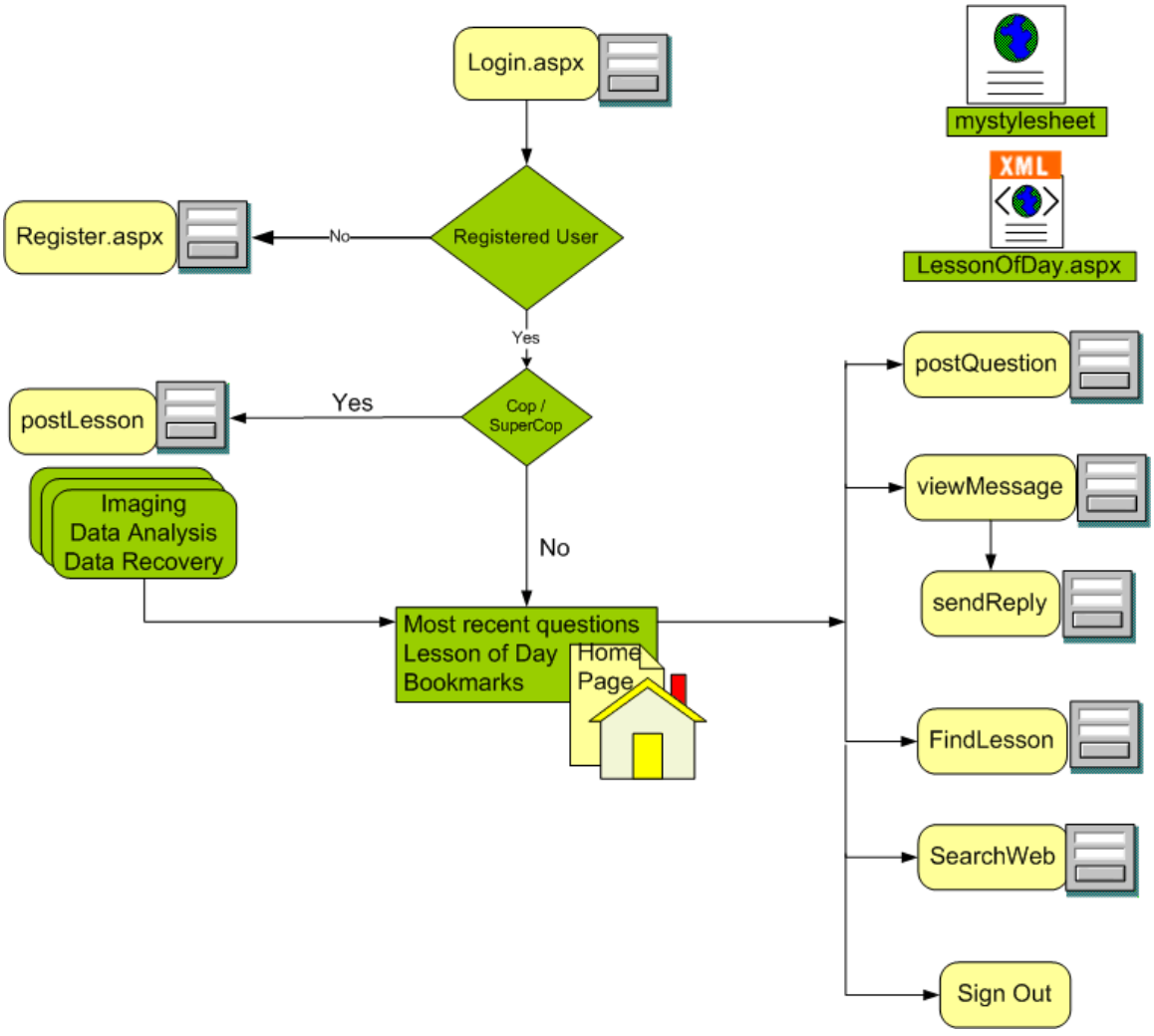


Figure 6.2 Functional architecture of the application

6.3 Utility Classes and Web Pages

Class Diagram

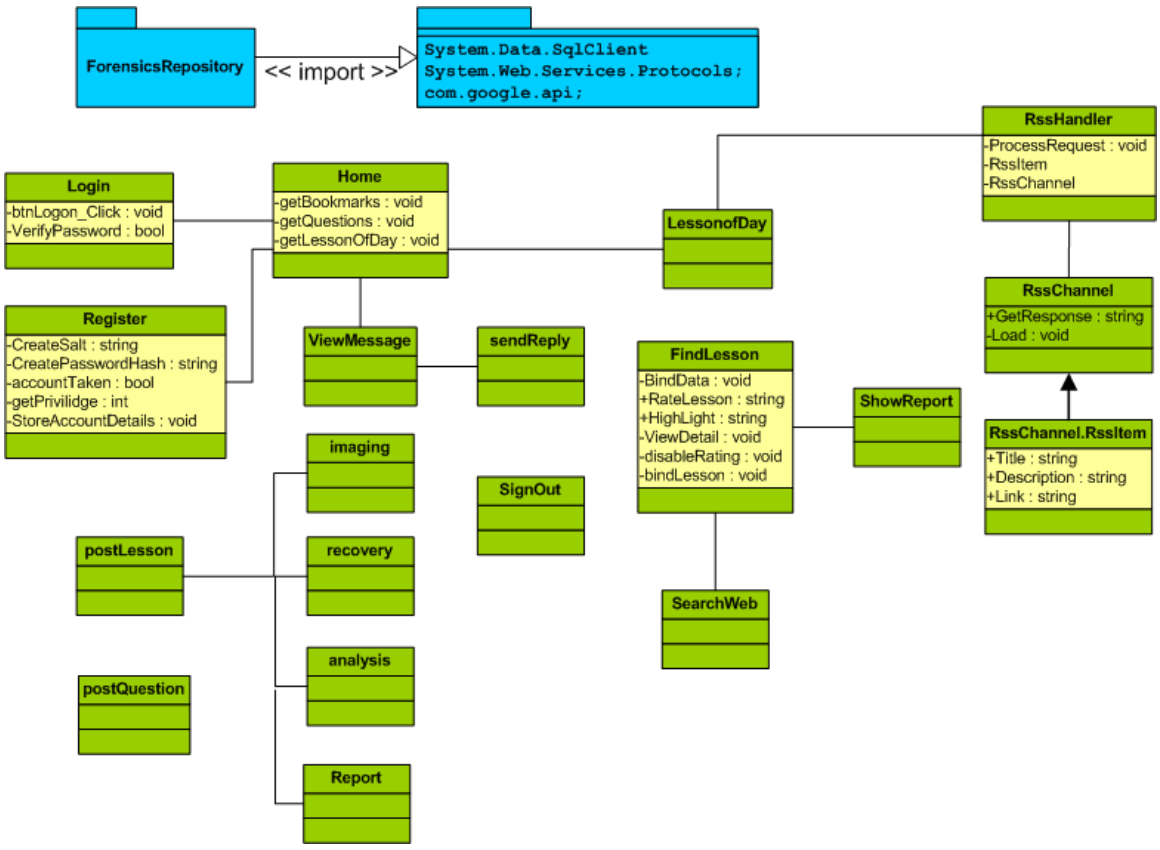


Figure 6.3 Class Diagram

Login.aspx

Processing Detail: This is the first screen of the application. The Login class authenticates the User using password hashing against a “repository” database contained in SQL Server 2000 and gets the User privilege level.

Register.aspx

Processing Detail:

1. Creates new user accounts
2. Checks for duplicate accounts
3. Stores user information in the Database

Home.aspx

Processing Detail: The Home page retrieves the top 5 most recent questions posted and the solutions if any, the lesson of the Day and the Bookmarks the User added from the database.

Mailing List

Users can post Questions, which can be answered by any other User. The mailing List session interacts in the following way amongst the pages postQuestion.aspx, ViewMessage.aspx and sendReply.aspx

postlesson.aspx

Processing Detail: Depending upon the phase selected, Imaging, data recovery, Data Analysis, user is brought to a page which indexes a list of investigative Suites/Tools, Devices, Operating Systems.

The User submits the lesson and depending upon the User's privilege level, the lesson is either added to the Database and available for other Users to view it, or is sent to a Supervisory board for approval, and posted later if approved.

On validation, the stored Procedure 'postLLearned' is executed, which stores the lesson into the Database. The User may also Upload a File that will be stored in the Database Table Uploads.

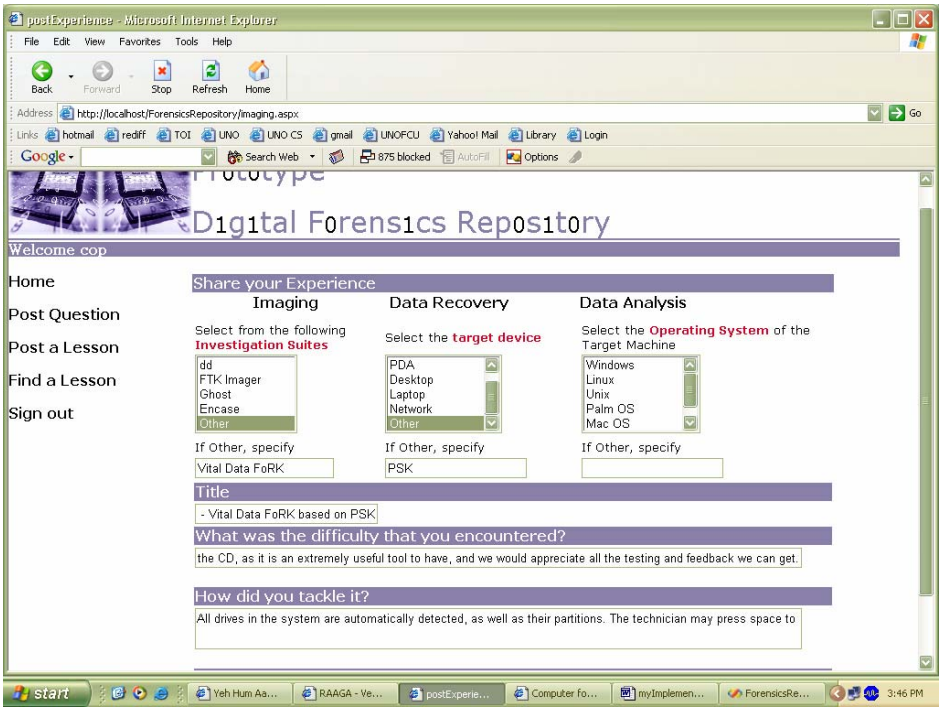


Figure 6.4 Snapshot

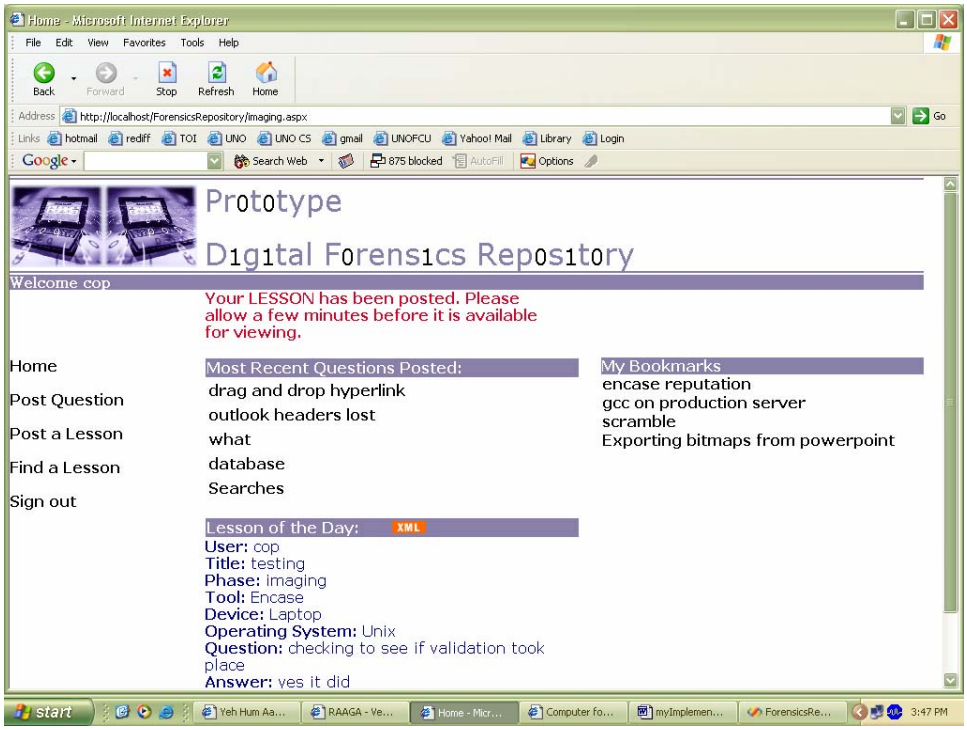


Figure 6.5 Snapshot

Findlesson.aspx

Processing Detail: This page retrieves lessons from the Database depending upon the indexes selected like investigative Suites, operating Systems, target device and the search word. The Database stores lessons in LLearned table. Only the title and keywords columns of the table LLearned are indexed for full-text searches. So it looks up for the search words in the title and keywords columns and returns the search results.

It also searches the Text/Html/Document/PowerPoint reports uploaded with the given search words and retrieves the documents. Users' bookmarks can also be viewed here. Users can rate lessons here upon retrieval.

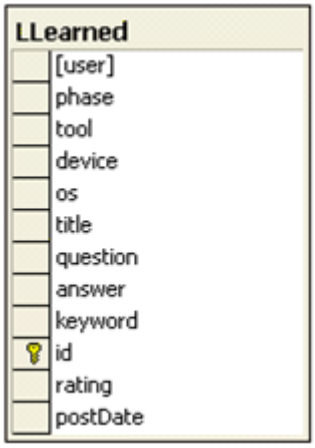


Figure 6.6 Database table LLearned

lessonOfDay.aspx

Depending upon User ratings a lesson of the day is chosen and converted into RSS Feed, so that the Users can use a RSS reader to receive these feeds everyday.

RSS Request Processing Detail:

The figure below [19] explains the RSS request processing Details. The client browser or RSS reader requests an RSS document from the site. IIS sees the .rss file extension and invokes .NET to process it. Based on information in the Web.Config file, .NET invokes HTTP handler, RssHandler, to process the request.

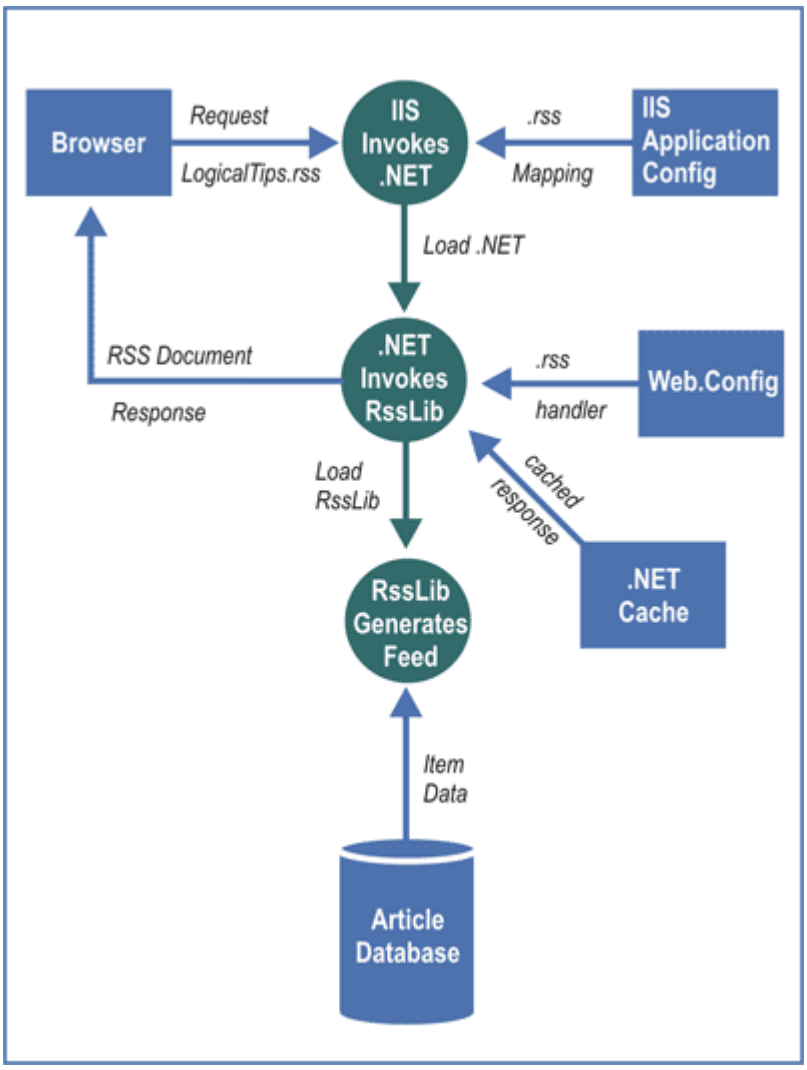


Figure 6.7 RSS Request Process

RssHandler.cs

RssHandler reads the channel profile and retrieves information about how to build the RSS document. RssHandler merges information from the profile with item data from the database to build the RSS document and sends it back to the browser. RSS is an XML Document. It consists of an RSS root node, a channel node, and a variable number of item nodes. The channel node describes the source of the content, and the item nodes describe individual resources provided by the channel.

```
- <rss version="2.0">
  - <channel>
      <title>Forensics Repository</title>
      <link>http://olaw2k3.cs.uno.edu/ForensicsRepository</link>
      <description>Forensics Repository</description>
      <language>en-us</language>
    - <item>
        <title>how to do steganalysis</title>
        <description>ftk imager doesnt do stego</description>
        <link>http://olaw2k3.cs.uno.edu/ForensicsRepository/ShowLesson.aspx?id=14</link>
        <pubDate>installed stego detect separately</pubDate>
        <guid isPermaLink="true">http://olaw2k3.cs.uno.edu/ForensicsRepository/ShowLesson.aspx?id=14</guid>
      </item>
    </channel>
  </rss>
```

Figure 6.8 Sample RSS XML Document

Chapter 7

Conclusion and Future Work

7.1 Conclusion

The rapid growth in technology and software has given birth to a new type of a crime, generally referred to as white collared crime, which involves stealing trade secrets, malicious virus attacks, hacking of DVD players, network attacks, etc. The law enforcement community which has been trained to deal with traditional form of crime is now being trained in a whole new realm of digital forensics. But even the most successful forensics training can only give common sense about computers and other digital devices. Most of the times, it is not even possible for investigators to repeat steps taken in previous cases due to the aforementioned problem. During the investigation, some configurations or devices occur infrequently enough that the solution, though known and previously used, is not clearly remembered and needs to be researched. Dealing with such issues can take days and weeks, following up dead ends and researching the technology. Available Hardware and Software tools also have limitations.

Forensics investigators have realized that often the most valuable resource available to them is the experience and knowledge of fellow technicians and investigators. But there is seldom an explicit mechanism for disseminating this knowledge. Hence the same problems and mistakes continue to resurface and the same solutions are re-invented.

The goal of maintaining a repository of lessons learned during the forensics investigation process is to collect information about experiences that will discourage the use of work

practices that lead to undesirable outcomes and encourage the use of work practices that lead to desirable outcomes.

In this Thesis we design and create a knowledge base, a digital forensics repository, to support the sharing of experiences about the forensics investigation process. It offers capabilities such as submission of lessons, online search and retrieval which will provide a means of querying into an ever increasing knowledge base. The web-based repository of digital forensics lessons classifies the available technologies, devices, tools, and procedures used during the investigation in a way that can be easier to retrieve and store lessons. We also provide a way for forensics investigators to post questions and get help from experts in this domain. That way user can get answers to questions that are not available in the repository. The repository application also aims at keeping the forensics officers alarmed of the experiences of other users by providing feeds on “lesson of the day”. We also allow Users to search existing forums such as http://www.forensicsfocus.com, Google and Yahoo Groups and incorporate their search results on our Webpage. When the Users finds a tutorial or lesson or article on the Web useful and would like to submit that article to the repository, then based on his privilege levels, he is allowed to save that article in the database.

The prototype is located at [14].

7.2 Future Work

In the current system, when searching for lessons, we search only the lessons stored in the Database and the Reports submitted by Users. As part of the future work, we would search the Questions and Answers posted by Users also. Currently Users are not able to

edit their lessons, once submitted. We would like the user to be able to modify lessons created by the User himself. Also, there is no limit on the number of bookmarks users can create. We would like to impose a restriction on the number of Bookmarks users can create and let the users be able to delete existing Bookmarks. Currently when the user creates a lesson by searching the Web, we save the link of the webpage in the database. In the future we would like to store only the Contents of the Page by means of an HTML parser.

Chapter 8

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Vita

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