TESTING DIGITAL FORENSIC STRING SEARCH TOOLS

James R. Lyle & Barbara Guttman
National Institute of Standards and Technology, 100 Bureau Drive Stop 8970, Gaithersburg, MD 20899-8970

Hi, I'm with the Computer Forensic Tool Testing Project at the National Institute of Standards & Technology. We develop test methods and test data for testing forensic tools.

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Tools and products mentioned (not endorsed): Autopsy, EnCase, FTK & X-Ways, MS Office, Mitsubishi and Subaru

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CFTT

The CFTT project at NIST develops methodologies for testing computer forensic tools. Currently there are CFTT methodologies for testing the following:

- Disk imaging*
- Write blocking*
- Deleted File Recovery
- File Carving
- Forensic Media Preparation
- Mobile Devices*

A variety of tools in each of these categories have been tested and observed flaws in the tools have been reported by the Department of Homeland Security (DHS) and the National Institute of Justice (NIJ). These results can be used as a basis for identifying the types of likely failures that occur in forensic tools.

* Starred methods have been incorporated into Federated Testing

We develop methodologies for testing forensic tools and we apply the methodology to specific tools and the Department of Homeland Security publishes the results. we are also developing Federated Testing to distribute the tool testing effort and sharing of test results. Jenise will be talking about that in

the next session.

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How to do a Test and What to Test?

- Need some test data -- basic idea
  - Put some strings on a hard drive
  - Make an image of the drive
  - Document the location of the strings; define expected results
  - Run the search tool, see if it can find the string
- What does find a string mean? & What should the tool report?
  - Location of match: file name, byte offset from somewhere
  - Actual string matched – may be searching with some option (e.g., ignore case)
- Some things that might matter for string searching:
  - Tool Settings: match case vs ignore case & word vs substring
  - Data Encoding: ASCII, UTF-8, UTF-16 (BE or LE)
  - What are the special cases? NTFS, meta-data, stemming

If you're going to test something, you need some test data. You also need to consider what attributes of the test data is likely to reveal something about the tool tested.

For string searching you need to know what strings are present and where the string you are looking for is. You also should have an idea of what you expect the tested tool to do.

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Logistics

- For string searching, CFTT provides test images with known content and a list of test cases designed to test specific features.

1. Tester can select relevant test cases from a list of test cases
2. Each case is run by first setting tool options and then searching for a string
3. Record search results
4. Generate a test report.

This is the general process for how we do testing. From a set of test cases select what applies to your situation and run those cases, configure the tool to run the case, Record the test results and when you finish create a test report.

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A basic test case

Case	Strings	Options	Case Description
FT-SS-01	DireWolf	Case = Match Case ASCII = True Unicode = False Whole Words = False	Search ASCII

ID	Byte Offset	Containing File	File System
0785	9207995	DELETED-Extinct-Lupus-fat-ascii.txt	fat32
0784	11006136	LIVE-Extinct-Lupus-fat-ascii.txt	fat32
0790	504553656	UNALLOCATED SPACE	unalloc
0787	1007456442	DELETED-Extinct-Lupus-exfat-ascii.txt	exfat
0786	1008124079	LIVE-Extinct-Lupus-exfat-ascii.txt	exfat
0788	1514692790	LIVE-Extinct-Lupus-ntfs-ascii.txt	ntfs
0789	1677365437	DELETED-Extinct-Lupus-ntfs-ascii.txt	ntfs

- Test image has 4 partitions: FAT, Unformatted, ExFAT & NTFS
- Test strings appear multiple (in this case 7) times with something different about each instance
- The search string appears twice in each formatted partition, once in unallocated space
- Each instance of the string has a unique ID, placed just after the string

This is a simple test case. The goal of a set of test cases in a DE lab environment is to try the tool features that are relevant to the DE Lab's work. Each individual test case will focus on a subset of tool features that are convenient to test together. In this test case, the main question examined is can the tool find an ASCII string. The secondary issues include: Type of file system, string surrounding environment: active or deleted file or unallocated space

and tool option settings.

Find the ASCII string "DireWolf". The string appears seven times in the test data. The test image has four partitions. Three partitions are formatted and one partition is unformatted (no filesystem). In the formatted partitions, two files are created with the test string in each partition. One file from each partition is then deleted. Another copy of a file with the string is added to the unformatted partition.

Most search tools return context around the string hit and this makes the string ID visible and helps identify the string instance found by the tool.

We also have a test image for Mac and Linux file systems.

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Results for a Simple String Search: Find "DireWolf"

DireWolf 6 Res

Table Thumbnail

Source File	Keyword	Keyword Preview
LIVE-Extinct-Lupus-ntfs-ascii.txt	DireWolf	Ocean? SEA ASCII ====> «DireWolf« 0788 <==== ntfs ...
LIVE-Extinct-Lupus-fat-ascii.txt	DireWolf	SHARK. SEA. ASCII ====> «DireWolf« 0784 <==== fat ...
LIVE-Extinct-Lupus-exfat-ascii.txt	DireWolf	tuna, Carp ASCII ====> «DireWolf« 0786 <==== exfat ...
DELETED-Extinct-Lupus-ntfs-ascii.txt	DireWolf	Brookbass ASCII ====> «DireWolf« 0789 <==== ntfs H...
DELETED-Extinct-Lupus-fat-ascii.txt	DireWolf	bass LAKE ASCII ====> «DireWolf« 0785 <==== fat Ba...
DELETED-Extinct-Lupus-exfat-ascii.txt	DireWolf	SHARK? bass. ASCII ====> «DireWolf« 0787 <==== ex...

Test Results for three common tools:

Tool	Hits	Misses
A	6	1
B	7	0
C	7	0

ID	Byte Offset	Containing File	File System
0785	9207995	DELETED-Extinct-Lupus-fat-ascii.txt	fat32
0784	11006136	LIVE-Extinct-Lupus-fat-ascii.txt	fat32
0790	504553656	UNALLOCATED SPACE	unalloc
0787	1007456442	DELETED-Extinct-Lupus-exfat-ascii.txt	exfat
0786	1008124079	LIVE-Extinct-Lupus-exfat-ascii.txt	exfat
0788	1514692790	LIVE-Extinct-Lupus-ntfs-ascii.txt	ntfs
0789	1677365437	DELETED-Extinct-Lupus-ntfs-ascii.txt	ntfs

Here is what one tool reported for DireWolf. This tool did not find the string in unallocated space. Why?

Maybe I configured the search wrong? Maybe my test data is not what I think it is? Maybe the tool does not search unallocated space? I tried two other tools and got all 7 hits. Need to note this and look for a pattern in other test runs?

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Test Case Summary with Expected Results

Adjust search tool parameters to the following:
Case = Match Case ASCII = True Unicode = False Whole Words = False

Search Strings:

Ask the search tool to look for each of the following strings:
DireWolf

Run the tool and record the results below.

Active Files		Deleted Files	
☐	0784 LIVE-Extinct-Lupus-fat-ascii.txt	☐	0785 DELETED-Extinct-Lupus-fat-ascii.txt
☐	0786 LIVE-Extinct-Lupus-exfat-ascii.txt	☐	0787 DELETED-Extinct-Lupus-exfat-ascii.txt
☐	0788 LIVE-Extinct-Lupus-ntfs-ascii.txt	☐	0789 DELETED-Extinct-Lupus-ntfs-ascii.txt

Unallocated Space	
☐	0790 504553656 985456 DireWolf

- Specifies what search options to select
- Specifies what string or pattern to search for
- Presents expected results – after running the search select the checkboxes to record all strings found
- Record false hits and other notable behavior in a comment text box (not shown)

This is a glimpse of what you need to run that simple test case and record the test results. Settings for the search tool to run the case and expected results to know what to expect.

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What We Selected to Test

- Match case vs Ignore Case
- Match whole Words vs substrings
- Search method: indexed vs live vs physical
- Encoding: ASCII, UTF-8, UTF-16(BE & LE)
- Language: CJK, Latin with diacritics, non-Latin, right-to-left
- Live Files vs Deleted Files vs Unallocated Space
- Logical expressions
- Regular expressions
- Special Cases
  - Meta-data
  - Formatted documents (.doc, .docx, .html)
  - Small files in NTFS $MFT
  - Search target spans fragmentation
  - Stemming

Here are the issues we considered for testing. We implemented test cases for these parameters because they might cause a search tool to reveal behavior that a user should be aware of. It turns out that these have been good choices because we often observe an unexpected result that could have been missed if we hadn't tested these parameters. For example, if we just tried UTF-8 text we wouldn't know if a tool misses UTF-16, both encodings

have potential for mishandling by a tool since both are present in almost every file system.

This is where CFTT test cases focus, there are plenty of other issues that we don’t investigate.

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Unicode Test Strings

- Each string appears multiple (21) times.
- Each string appears in an active file and a deleted file.
- Each string appears in 3 formatted partitions: FAT, ExFAT, NTFS
- Each string appears in 3 UNICODE encodings: UTF-8, 16BE, 16LE
- Each encoding appears once in unallocated space.

String Class	Strings
Kanji: Japanese & Chinese	東京 Tokyo (Japanese) 中国 China (Simplified Chinese)
Hangul: Korean	서울 Seoul (Korean)
Kana: Hiragana & Katakana	スバル Su ba ru (Katakana) みつびし Mi tsu bi shi (Hiragana)
Cyrillic: Russian	Сибирь Siberia (Russian)
Latin: French & German	Garçon Boy (French) Schönheit Beauty (German)
RTL: Arabic	الكسكس The Couscous (Arabic)

Let's take a look at UNICODE searching. UNICODE testing can be very complicated; we can’t test everything that could be tested, so we tried to cover some high level features. Each of the strings has a different feature: Kanji, kana, hangul are all different scripts, A Chinese character may have two versions: traditional or simplified, the first character of Tokyo is also traditional Chinese, last character of China is a simplified character, Boy and

Beauty have diacritical marks and Arabic is written Right-to-left.

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Unicode Search Results – Tool A

CASE	TARGET STRING	ACTIVE FILES			DELETED FILES			UNALLOC SPACE		
		Targets	Hits	Misses	Targets	Hits	Misses	Targets	Hits	Misses
FT-SS-07-CJK-CHAR		18	6	12	18	6	12	6	2	4
	中国	9	3	6	9	3	6	3	1	2
	東京	9	3	6	9	3	6	3	1	2
FT-SS-07-CJK-HANGUL		9	3	6	9	3	6	3	1	2
	서울	9	3	6	9	3	6	3	1	2
FT-SS-07-CJK-KANA		18	6	12	18	6	12	6	1	5
	スバル	9	3	6	9	3	6	3	0	3
	みつびし	9	3	6	9	3	6	3	1	2
FT-SS-07-CYRILLIC		9	3	6	9	3	6	3	1	2
	Сибирь	9	3	6	9	3	6	3	1	2
FT-SS-07-LATIN		18	6	12	18	6	12	6	1	5
	garçon	9	3	6	9	3	6	3	1	2
	Schönheit	9	3	6	9	3	6	3	0	3
FT-SS-07-RTL		9	3	6	9	3	6	3	1	2
	الكسكس	9	3	6	9	3	6	3	1	2

Most UTF-8 strings found, UTF-16 strings usually not reported (missed)

Here are the results for the UNICODE tests run against tool A. The misses column should contain only zeros. Oh dear, they are not all zeros here! Tool A is missing the UTF-16 copies of the strings. It also sometimes reports a string from a deleted file as belonging to unallocated space.

Let's try another tool.

Unicode Search Results – Tool B

Case	Expected String	Active Files			Deleted Files			Unalloc Space		
		Expected	Hits	Misses	Expected	Hits	Misses	Expected	Hits	Misses
FT-SS-07-CJK-char		18	18	0	18	18	0	6	6	0
	中国	9	9	0	9	9	0	3	3	0
	東京	9	9	0	9	9	0	3	3	0
FT-SS-07-CJK-hangul		9	9	0	9	9	0	3	3	0
	서울	9	9	0	9	9	0	3	3	0
FT-SS-07-CJK-kana		18	18	0	18	18	0	6	6	0
	スバル	9	9	0	9	9	0	3	3	0
	みつびし	9	9	0	9	9	0	3	3	0
FT-SS-07-Cyrillic		9	9	0	9	9	0	3	3	0
	Сибирь	9	9	0	9	9	0	3	3	0
FT-SS-07-Latin		18	18	0	18	18	0	6	6	0
	garçon	9	9	0	9	9	0	3	3	0
	Schönheit	9	9	0	9	9	0	3	3	0
FT-SS-07-RTL		9	9	0	9	9	0	3	3	0
	الكسكس	9	9	0	9	9	0	3	3	0

All instances of search targets found

OK, no anomalies here.

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Searching Formatted Text – MS Word, HTML

- Each string appears four times
  - Plain Text in FAT partition
  - Formatted Text in FAT partition
  - Plain Text in unallocated space
  - Formatted Text in unallocated space
- Formatting schemes used
  - MS Word .doc & .docx
  - HTML
- Part of the string is formatted bold and underlined
  - **Cross**Bow HTML <u>Cross</u>Bow
  - **Nitro**glycerin DOCX
  - **Shot**gun DOC

Let's look at text with embedded formatting. Often text such as HTML or MS Office is stored this way with embedded tags. The list of possibilities is long. Look at crossbow. To match CrossBow a search tool has to ignore the bold and underline tags.

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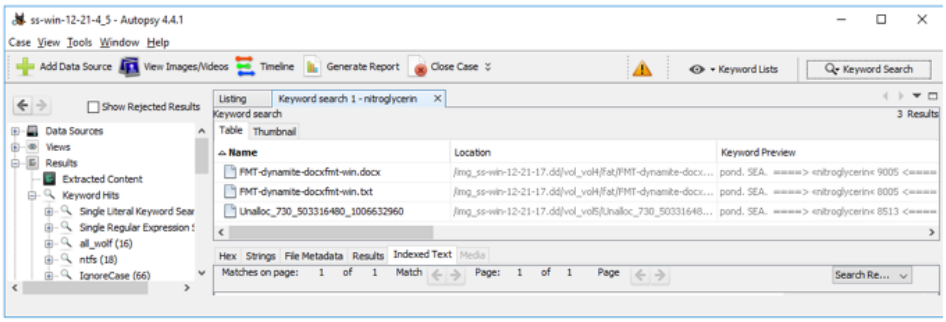
Formatted Text Searches – Find **nitro**glycerin



The string nitroglycerin appears 4 times:

- Text in the FAT Partition (8005) and in unallocated space (8513)
- Formatted text in a docx file: **nitro**glycerin (9005 in FAT and 9513 in unallocated space.
- This tool found formatted text in FAT, but no tool found string in unallocated space.
- Tried two other tools with slightly different results

This is cool, nitroglycerin is formatted with embedded tags for the bold and underlining and packaged in a DOCX file which is really XML in a ZIP file.

I'm not sure it's fair to expect it to be found in unallocated space, may need to do file carving first before searching. Tool A found the HTML case, but tool B didn't. Tool C found the formatted string in both DOCX & HTML using indexed search, but

missed both using a live search. I suspect I need to configure the search better.

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Unexpected Results

If a tool returns an unexpected result for a test case . . .

- Tool is not designed to do what the user expects (it's a feature)
- Tool is not implemented to correctly do what the designer intended (It's a bug)
- Tool is not configured to do the exact task the user wants (User error, read the documentation again)

Just because a tool being tested doesn't do what you wanted, it doesn't mean the tool made an error. It could be a feature instead of a bug or you could have messed up making the test data, messed up running the test or misinterpreted the results.

Knowing about problematic tool behaviors provides an opportunity to mitigate the effects.

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Things Learned Making Test Data

MFT: *fixups* and the *Update Sequence Array.*

- I noticed my string documentation program sometimes missed strings that I knew were in the test image, but forensic string search tools could find the strings that my program missed.

Copy/Paste from PDF may not do what you expect.

- One day I noticed that none of the tools found Arabic text anymore.
- I was copying/pasting from a PDF.
- Arabic + PDF = Weird. The string renders correctly in the search tool, but the byte codes copied are not UNICODE.

Keep in mind that tool testing is a chance for you to learn things. It takes a lot of work to ensure that that a test data set will function as intended. Sometimes during the quality control process unknown unknowns reveal themselves in interesting ways.

I found a mystery one day. I have a program that examines my test image and reports all the locations for each test

string. Sometimes it missed strings that it should have found, so I used a hex editor and tracked down the strings and sure enough they had two bites of corruption. Now the cases where this showed up were all for special test with NTFS filesystems. If you have a really small file it is actually stored in the MFT. The corruption was the fix up byte at the end of the sector.

My other mystery showed up when Arabic searches stopped working, not just for one tool but all the tools. it turns out that the way Arabic was stored in my PDF file was not what I expected, so the copy/paste didn't transfer something that would match in the search. I’m still looking at the issue but copy and paste from PDF may get you something unexpected.

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Some Observed Tool Behaviors

- All tools could parse FAT, ExFAT, NTFS, ext4, journaled OSX and case-sensitive OSX partitions.
- Usually found ASCII, UTF-8 & UTF-16, but sometimes failed to find UTF-16 strings
- Sometimes indexed search and live search have differences.
- Sometimes UTF-16BE reported as UTF-16LE and vice versa
- Usually 1-1 reporting of each hit to location, but sometimes reported as multiple hits
- One older tool version reported a corrupted name for some ExFAT files containing a hit
- One tool fails to render Korean UNICODE string correctly
- Some tools fail to ignore embedded HTML tags
- Most tools failed to recognize and decode docx file in unallocated space

These are some of our preliminary observations from informal trials of some widely used forensic tools. More complete formal testing is coming soon.

Most of these behaviors are situations where the search tool might miss a string.

I didn't see any situations where a tool said that something was in the image when it wasn't there.

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What Does Software Testing Get you?

- Tool testing catches specific errors thus **increasing your confidence in the tool**
- Testing NEVER can PROVE a program is always correct.
- Software Testing is asking questions to see how the tested tool reacts to various inputs
- If software gives an unexpected result it usually is triggered by a specific condition
- Better understanding comes from trying more conditions . . .
  - More diversity of questions
  - More detailed questions
- Testing documents tool behaviors that you need to be aware of

As you have hopefully seen, our string search test cases shows that string search tools work in general and will alert the forensic practitioner to limitations that can be mitigated.

It is challenging to find the right questions. You want each question to bring something unique to the test. You want each question to encourage the tool to do something different. With this test

data we found different behavior based on file system, search method (engine), character encoding, language, active-deleted state, and formatted file type.

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Coming Soon -- Federated Testing with String Search
http://www.cftt.nist.gov/federated-testing.html

Sharing CFTT Test Methods, Tools & Forensic Lab Test Reports

- Helps a forensic lab test tools easily and with high quality
- For string searching CFTT provides test images with known content and a list of test cases designed to test specific features.
  1. Tester can select relevant test cases from a list of test cases
  2. Each case is run by first setting tool options and then searching for a string
  3. Federated testing tool records search results
  4. Tool to generate a skeleton test report that can then can be finished in the style favored by the laboratory.
- The test reports can be shared with other labs

The goal of federated testing is to move high quality testing to labs and to produce more test reports for more tools to enable sharing the tool test results. Federated testing makes the NIST test methods available to a wide audience of users so that many organizations can use the same method to test tools and produced test reports in a similar format. By using the same or similar test data it is easy to compare results for testing tools by

different organizations. In this way, labs can help each other too. Jenise will say more about federated testing.

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Contact Information

Jim Lyle
jlyle@nist.gov
http://www.cftt.nist.gov

E-Mail federatedtesting-request@nist.gov with the word "subscribe" (without quotes) in the subject line tosubscribe to the federatedtesting@nist.gov mailing list. Federatedtesting@nist.gov is a low volume mailing list for distributing updates on the Federated Testing project and the Federated TestingForensic Tool Testing Environment (e.g., new releases/versions and capabilities).

Get on the mailing list if you want to know about federated testing.

Questions?

Thank you for your attention.

Bye now.