TOOL VALIDATION: WAS THAT SUPPOSED TO HAPPEN?

NIST PERSPECTIVE AND PROGRAMS

JIM LYLE

cftt@nist.gov

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NIST & CFTT

- CFTT – Computer Forensics Tool Testing project
- Established in 2000 to provide a methodology for testing computer forensic software tools
- Develop . . .
  - Tool Requirements
  - Methods to test tools against tool requirements
  - Test data sets (CFReDS) and tools to generate test data sets
- Federated Testing – Test plan in a box: select test data, run tests, record results, generate standard format test report and share results.

CFTT TESTING

There are CFTT test methodologies (requirements and test plans) & Test Reports for:

- Digital Data Acquisition
- Write Blocking
- Drive Wiping
- Deleted File Recovery (Meta-data based)
- Registry Forensics
- String Search
- Mobile Devices
- File Carving

5 CHARACTERIZING RELIABILITY

- Daubert – criteria to help assess reliability admissibility of scientific testimony
    - Tested
    - Peer review
    - Error rate
    - Standards & controls
    - General acceptance
- Daubert, Kuhmo Tire & GE v. Joiner.
- FRE 702

ARE THE RESULTS OF A FORENSIC EXAM RELIABLE?

- The court wants to know if results are reliable.
- Digital & Multimedia Forensic practitioners are confident that tools and methods are reliable, but . . .
- Saying "I know it works" is just not acceptable. There needs to be some objective support to the claim.
- How to characterize and communicate tool reliability?
- Other forensic disciplines use error rates to describe chance of false positive, false negative or otherwise inaccurate results.
- Why not Digital?

ADDRESSING DAUBERT

- Error Rate works great to characterize matching two items –
- Examples:
  - Using hashes to see if two files match or if a file has changed
  - DNA
- Error Rate is not so great on characterizing software tools because of the way software fails
- Examples:
  - Might systematically omit something – Partial acquire
  - Might put unrelated items together –
    recover a file with data from multiple sources
- Testing is a dark art – studied since the 1950's, but software is still buggy

ERROR RATES

- Error rates are usually statistical in nature or there is some kind of random variable from a population
- Usual way to compute an error rate for a method is to study a large population and count the number of times the method gives wrong answers.
- With digital data the technology changes rapidly and new technology often changes the proportion of right and wrong answers.
- For deleted file recovery the file system format: matters: FAT, NTFS, ExFAT, HFS+, APFS, ext4
  - Need different deleted file recovery algorithms for each
  - Fat only points to first block, NTFS has pointers to all blocks, HFS+ clears all block pointers

ALGORITHM VS IMPLEMENTATION

- Error rate for Hash algorithms is based on the math in the algorithm, but actual performance is based on the implementation.
- Are two files the same – The probability two file hashes match is a very very very very very small number that is close to zero.
- An implementation may have an error rate quite different from the algorithm
- It depends on how software can fail . . .

HOW DOES SOFTWARE FAIL?

- Software failure is not statistical in nature . . .
- Software (usually) does the same thing (wanted or not) with the same input. – systematic errors
- But wait, you often see the question "What is the error rate of this or that tool?"
- For software this is the wrong question. It is possible to derive an error rate from observation of a large number of trials, but the rate is an average and not relevant to any specific case
- Need to ask what limitations have been revealed by testing?
- Keep in mind that technology changes steadily

FORENSIC TOOL FAILURE EXAMPLES

- Acquire Digital Data
  - Fail to acquire last few sectors of a device
  - Report incorrect digital device size
  - Treatment of bad sectors
- Write Block
  - Fail to block all write commands on all interfaces
  - Block some read commands too.
- Mobile Devices
  - Partial acquire of some artifacts
  - Get the phone’s number wrong
  - Different failures for different devices

13 MORE TOOL FAILURES

- String Search
  - Strings missed in specific combinations of parameters, e.g., UTF-8 Chinese found, but not if UTF-16
  - Latin based character string (English, French, German, Italian, etc.) reported twice for UTF-16, reported once for UTF-8.
  - ASCII strings not found in unallocated space.
- File Carving for JPG, GIF, TIFF, etc . . .
  - Tool reported lots of false positives
  - Tool confused by file fragmentation
  - Color map corrupted
  - Carved file has elements from more than one source

14 V VS V – TERMINOLOGY

- Verification is the same as Validation, Right?
- Lots of confusion – NIST/CFTT just uses "tool testing"
- Usual English definition of **verification***: the process of establishing the truth, accuracy, or validity of something.
- Usual English definition of **validation***: the action of checking or proving the validity or accuracy of something.
- In the Software Engineering context, a subtle distinction:
  - Validation: Check if building the right tool – testing & design review
  - Verification: Check if the tool is built right – software testing

* Definitions from Mac Dictionary app

SOFTWARE V&V

- Software Validation: The process of evaluating software during or at the end of the development process to determine whether it satisfies specified requirements. [IEEE-STD-610]
- Software Verification: The process of evaluating software to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase. [IEEE-STD-610]
- Software validation ensures that "you built the right thing" and confirms that the product, as provided, fulfills the intended use and goals of the stakeholders.
- Software verification ensures that "you built it right" and confirms that the product, as provided, fulfills the plans of the developers.

TO DO LIST FOR TESTING

You need three things:

1. Decide what the tool or process needs to do – write requirements
2. Decide on a method (algorithm) to meet the requirements
3. Implement the selected algorithm (Write software)

- Validation is checking if the algorithm meets the requirements
- Verification is checking that the software correctly implements the algorithm

HOW TO TEST SOFTWARE

- As many different methods as there are programmers
- Lots of general approaches – details differ – in general it's all about failure
  - Start with requirements
  - Make a list of items that can be tested (i.e., you can create a test case that can fail)
  - Create test data sets
    - You need to have tight control of everything
    - You need to know what results the tool should report
    - It's tempting to use the data from the last several investigations with multiple tools to try and establish what a tool should report, but this is not reliable and you don't know if it contains data elements you need
  - Run the test cases

18 TESTING EXAMPLE – FILE CARVING

- Many file types have recognizable signatures in the file data
  - Graphic – jpeg, gif, png, bmp & tiff
  - Video – mp4, wmv, 3gp, ogv, mov, avi
  - Document – doc, docx, xls, xlsx, pdf, ppt & pptx
  - Archive – zip, rar, 7z, gz & tar
  - Others -- ???
- Can't test all at once

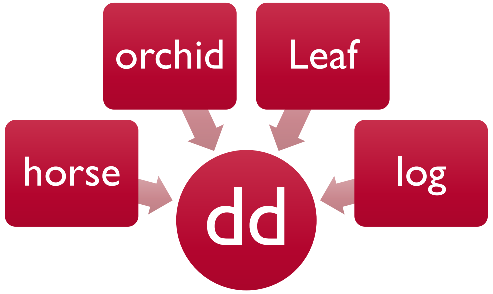
19 TESTING ISSUES -- IDENTIFY REQUIREMENTS

- Dozens of parameters that might affect tool behavior
- Focus on most important parameters
  - Completeness
  - Fragmentation
  - Embedded pictures (thumbnails)
  - Tool option settings (use default values)
- Be aware of other issues like . . .
  - File type specific characteristics
  - Compression level
  - Thumbnails
  - EXIF data
  - Audio track

DATA SETS FOR GRAPHIC FILES

- Collection of separate graphic files:
  - Barn.gif
  - Winter.tiff
  - River.png
  - Oak.jpg
  - Also bmp
- Eight files of each type
- Can construct "dd disk image file"

BASE DD FILE – COMPLETE & CONTIGUOUS PICTURE FILES



orchid

Leaf

horse

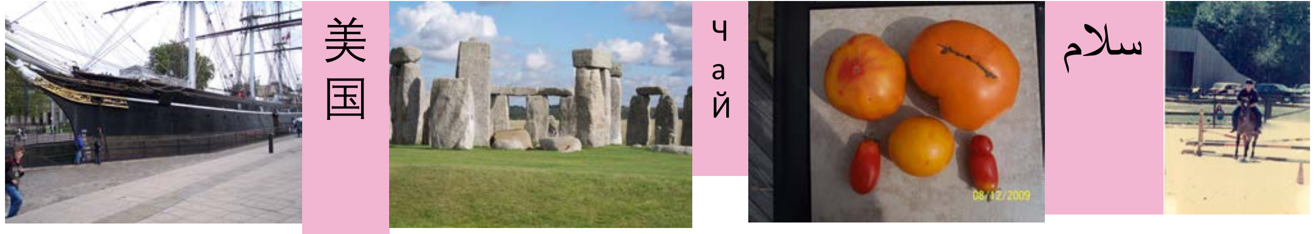
log

dd

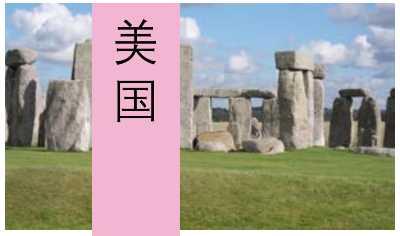
Zero fill to end of last sector

CONSTRUCTING OTHER IMAGES

- Padded with cluster sized blocks of non-English text between pictures



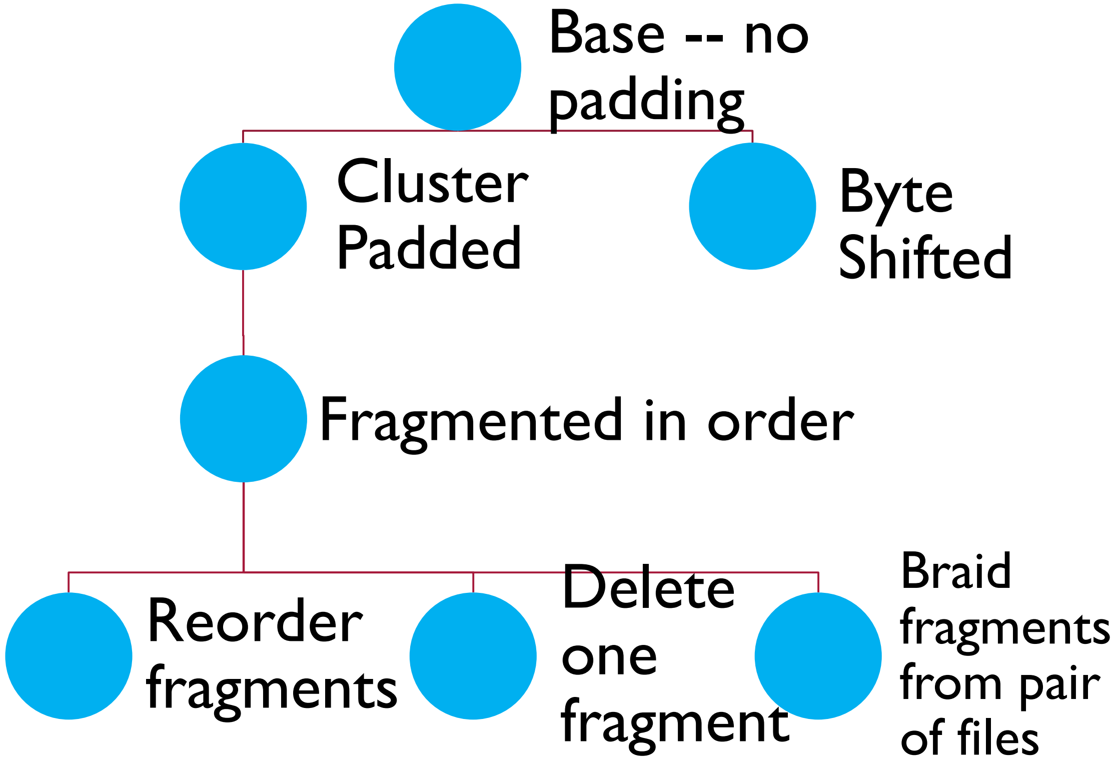
- Fragmented (in order)



Other dd images

- Fragmented (out of order)
- Braided (two files intertwined)
- Incomplete files
- Non-aligned to sectors

23 CARVING TEST IMAGES



Base -- no padding

Cluster Padded

Byte Shifted

Fragmented in order

Reorder fragments

Delete one fragment

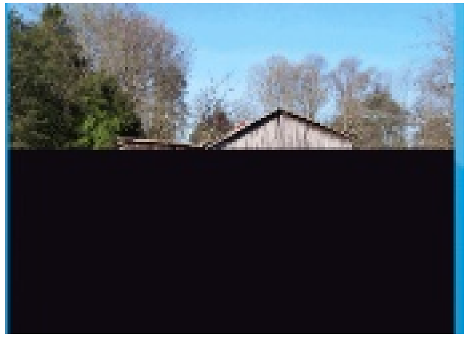
Braid fragments from pair of files

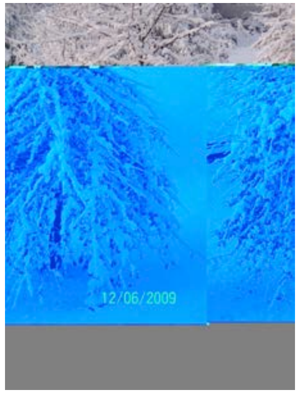
MEASURING RESULTS

- Two approaches –
  - Visibility driven – does the tool produce usable (viewable) results
  - Data driven – See what the tool actually does in relation to ground truth
    - Measure fraction of returned data that belongs
    - Measure fraction of possible data returned
- Methods are complementary

VISIBILITY DRIVEN MEASUREMENT

- Each file checked for visibility by two independent observers
- Resolve differences if disagreement





Category	Visibility
Viewable Complete	Flaws – minor or none
Viewable Incomplete	Flaws – partial, multiple files
Not viewable	Data matches file type, Flaw prevents display
False Positive	Data doesn’t match file type

DATA-DRIVEN MEASUREMENT

- We know the ground truth
- Based on sectors present in carved files and information retrieval based statistics – evaluate returned data
  - Relevant – sector comes from a source file in dd file
  - Retrieved – sector returned in a carved file
- P = (relevant ∧ retrieved)/retrieved -- fraction of retrieved sectors from a source file -- **how much noise returned**
- R = (relevant ∧ retrieved)/relevant – fraction of relevant sectors retrieved – **how much stuff missed**
- F = 2 x (P x R)/(P + R) - average of P & R

A RABBIT-HOLE OF INTERESTING BEHAVIOR

- One tool (A) recovered 8 tiff files from the unpadded dd file
- F score for tiff files was 1.00
- But, only one file was viewable, seven were not viewable
- Examination of the eight files – last sector of tiff file replaced by noise in the carved file
- That last sector is critical to having a displayable file
- Other tools on same data –
  - Tool B Carved 4 with 3 viewable
  - Tool C Carved 10, none viewable
  - Tool D Carved 8, all viewable
- Without both measures we wouldn't know how close the tool was. Maybe an investigator can repair the file and extract a critical piece of evidence

OTHER RESOURCES

- www.SWGDE.org
- CFTT & CFReDS:
  - www.cftt.nist.gov -- Test Requirements, Test Plans & Tool Test Reports
  - www.cfreds.nist.gov – Test Data Sets
- UK Forensic Science Regulator:
  - https://www.gov.uk/government/organisations/forensic-science-regulator
  - https://www.gov.uk/government/publications/method-validation-in-digital-forensics

SUMMARY

- Most tasks not likely to have an error rate (except for some tasks like matching)
- Even if you have an error rate it can be misleading or obsolete
- Use tool testing to uncover tool limitations
- Work from a list of requirements
- Design Test Data to try to get the tool to fail sidetracked
- Look at SWGDE ”Error Mitigation Document” for guidance on reporting on tool limitations

CONTACTS

Jim Lyle
JLYLE@NIST.GOV

Barbara Guttman
BARBARA.GUTTMAN@NIST.GOV

Rick Ayers
RICHARD.AYERS@NIST.GOV

http://www.cfreds.nist.gov	Test Data Sets
http://www.cftt.nist.gov	Test Reports