If Error Rate is Such a Simple Concept, Why Don’t I Have One for my Forensic Tool Yet?

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Introduction

• Daubert – criteria to assess admissibility of scientific testimony
  o Tested
  o Peer review
  o Error rate & controls
  o General acceptance

• The first idea (using tool test results) for establishing an error rate doesn't work.
First try for an Error Rate Fails

- Consider disk imaging . . .
  - Let n be total bits acquired
  - Let k be number of incorrectly acquired bits
  - Then k/n looks like an error rate.
- But, how to determine n & k is hard.
- Doing lots of acquires may not get a representative sample of drives that might be imaged.
Outline

- Typical errors seen during testing
- Measurement & Statistical Errors
- Sources of Errors
- An Example
- Establishing Error Rates
- Summary
Disk Imaging Behaviors

- Some sectors omitted
  - 1024 sectors for Quantum Sirocco (SafeBack)
  - 5040 sectors for Quantum Sirocco (EnCase 3)
  - 1 sector if drive has an odd number of sectors (dd Linux)
  - Last 8 sectors of NTFS logical drive (FTK)
  - Last sector of NTFS logical drive (EnCase 4, 5 & 6) and seven sectors prior to last sector are a repeat from earlier in the image.
- Sectors around a faulty sectors replaced by zeros
- HPA & DCO
Testing a Hypothesis –
Does entity X have attribute A?

- Statistical process
- A Matrix of possibilities

<table>
<thead>
<tr>
<th>Test Result</th>
<th>Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>X has A</td>
<td></td>
</tr>
<tr>
<td>X does not have A</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>X has A</th>
<th>Accept</th>
<th>False Positive aka Type I Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>X does not have A</td>
<td>False Negative aka Type II Error</td>
<td>Reject</td>
</tr>
</tbody>
</table>

Error rate for each type of error is the probability of the error occurring.
Sources of Error

- The theory of measurement error identifies two classes of errors: measurement (random process) & systematic (non-random)
- For forensic tools that implement some algorithm . . .
  1. An algorithm may have a theoretical (random process) error rate
  2. An implementation of an algorithm may have systematic (non-random) errors
  3. The execution of a procedure may have a blunder that affects the result
- Daubert is mostly interested in the first two.
Error Source Example

- Hashes or checksums (with useful attributes) can be computed for a file.
  - Same files have the same hash
  - A different hash means files are different
  - However, the same hash is possible for different files
- Hashes or checksums can be used to determine if:
  - A file has changed, or
  - If two files might be the same with some error rate.
An Algorithm To Compare A Pair Of Files With Only One File

- A hash or checksum can be used to determine if any file in a set of files match a given file.

1. Let c be the hash of the given file
2. For each file, f, in the set ...
   i. Compute, h, the hash of f
   ii. Compare c to h
   iii. If c matches h, then declare c equals h

- Hashes can collide (two different files with same hash)
- The error rate (type I) of file matches is related to the size of the hash (number of bits)
- The error rate (type II) for identifying two identical files as different is zero.
Comparing Randomly Selected Files

Chance of hash or checksum for a random file matching a given value

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Chance of Collision</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRC-16</td>
<td>1 in 32,768</td>
</tr>
<tr>
<td>CRC-32</td>
<td>1 in 2,147,483,648</td>
</tr>
<tr>
<td>MD5 (128 bits)</td>
<td>1 in 170141183460469231731687303715884105728</td>
</tr>
<tr>
<td>SHA-1</td>
<td>1 in $2^{159}$</td>
</tr>
<tr>
<td>SHA-256</td>
<td>1 in $2^{255}$</td>
</tr>
</tbody>
</table>
Implementation Errors

- A variety of implementation errors are possible, some are quite subtle.
  - One common error occurs as follows:
    - Hash algorithm is implemented in a UNIX environment. It works for any file.
    - Same program is moved to MS Windows environment. It works fine for any binary file, but computes a different (wrong) value for any text file (Windows adds a character to the end of each line of text).
What is the error rate?

• In the science of measurement error analysis an implementation error is called a *systematic error*.
• The distribution of text and binary files varies from computer to computer.
• There is no random distribution to the manifestation of the error.
• The implementation error is triggered only under some set of conditions.
• A tool may have implementation errors, but the algorithm being implemented has a statistical error rate.
Human Errors

- Human errors (blunders) occur
- Difficult to quantify
- Good processes have built in checks to detect blunders
Error Rate for Disk Imaging

- Forensic tools often have multiple requirements.
- Each requirement may generate a separate error rate.
- Separate the algorithm from the implementation.
- Algorithm is . . . Read and make a copy of every accessible sector on the drive. The error rate is zero.
- The implementation may have a many different systematic errors.
- Alternate algorithm . . . Add an attempt to read additional (not accessible) sectors – Unknown error rate.
Other Error Rates

- Write blocking
- String Searching
- File Recovery and Carving
Summary & Observations

- Distinguish between intended algorithm and actual implementation
- Algorithm may have an error rate (statistical in nature)
- Implementations have systematic errors
- Most digital forensic tool functions are simple collection, extraction or searching operations with a zero error rate for the algorithm.
- Tools tend to have minor problems, usually omitting data, sometimes duplicating existing data.
- An implementation’s systematic errors can be revealed by tool testing.
- To satisfy the intent of Daubert, tools should have the types of failures and triggering conditions characterized.
Project Sponsors (aka Steering Committee)

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- Homeland Security (Major funding)
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- Internal Revenue, IRS (Technical input)
- NIST/OLES (Program management)
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