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File carving

Computer Forensics

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Agenda

- What is file carving and why do it?
  - → Deleting files in NTFS and EXT3
  - → Main problems
- Simple file carving
- The file carving process
- File carving software
  - → Scalpel
  - → X-Ways Forensics
  - → CarvFS
  - → Sliding Entropy
- Semantics-based file carving

What is "file carving"?

- Recovering a file from unstructured digital forensic images
  - → "Unstructured" → File **meta**data is no longer available
  - → I.e., the file **content** is (partially) still on the disk (as sectors), but the sequence of the sectors as well as start, end, length, owner etc. is missing
- Typically last effort: No "undelete" poss., but still suspicions
  - → E.g. keyword searches of the whole disk found something
- Reasons for file carving
  - → The file system was damaged or deleted
  - → Using a modern file system (e.g. ext3)
    - » They overwrite important data on deletion
    - » But typically low level of file fragmentation (→easier carving)!
  - → Hard disks are in use for a long time and are faster
    - » Less need for defragmentation; defragmentation more difficult (and therefore rarer) on modern file systems

EXT3 delete

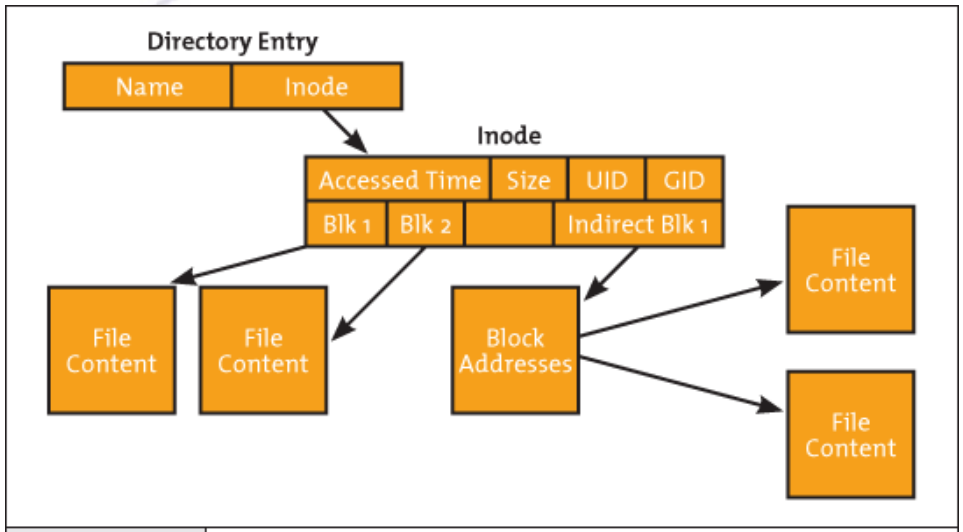


FIGURE 1 RELATIONSHIP BETWEEN THE DIRECTORY ENTRY, AN INODE, AND BLOCKS OF AN ALLOCATED FILE

Before deletion
(file still exists)

After deletion
(file removed)

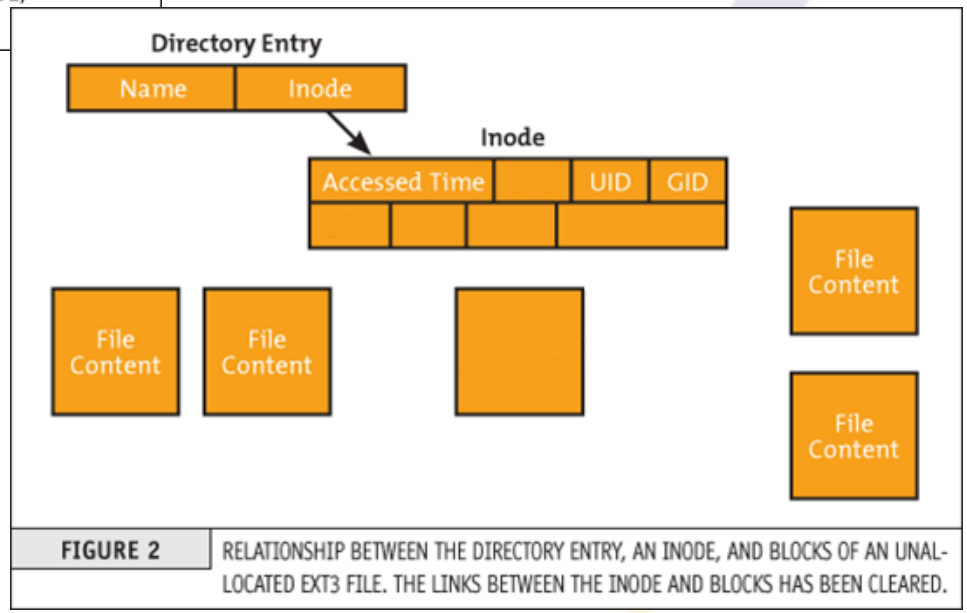


FIGURE 2 RELATIONSHIP BETWEEN THE DIRECTORY ENTRY, AN INODE, AND BLOCKS OF AN UNALLOCATED EXT3 FILE. THE LINKS BETWEEN THE INODE AND BLOCKS HAS BEEN CLEARED.

Main problems of file carving

- File carving has a time complexity of NP-complete
  - → You must try all possible combinations of fragments/sectors
  - → Optimizations are possible to reduce this
    - » Depending on the file type in questions
    - » Depending on the file system used
    - » Depending on additional information, e.g. content redundancy
- File systems become ever larger
  - → ≥ 500 GB hard disks are inexpensive and common
  - → Huge numbers of files and huge numbers of fragments!
    - » But individual files usually lightly fragmented
- File start is at sector boundary, but end not (slack space!)
- Files may be incomplete
  - → Start/end/middle sectors may have been reused for new files

Simple file carving

- Identify start & end of file and extract everything in between
  - → Example: JPEG (Start = FFD8, End= FFD9)
- Works only for file types with a specific end marker
  - → Will only find files with existing beginning (marker)
    - » First cluster lost → Gone!
  - → If no end marker exists: Specify a maximum length
    - » Everything up to then will be extracted
      - – Most programs will just ignore everything after "their" end
    - » Other option: Some file types have a length indicator at start
      - – Requires parsing the file according to its internal structure

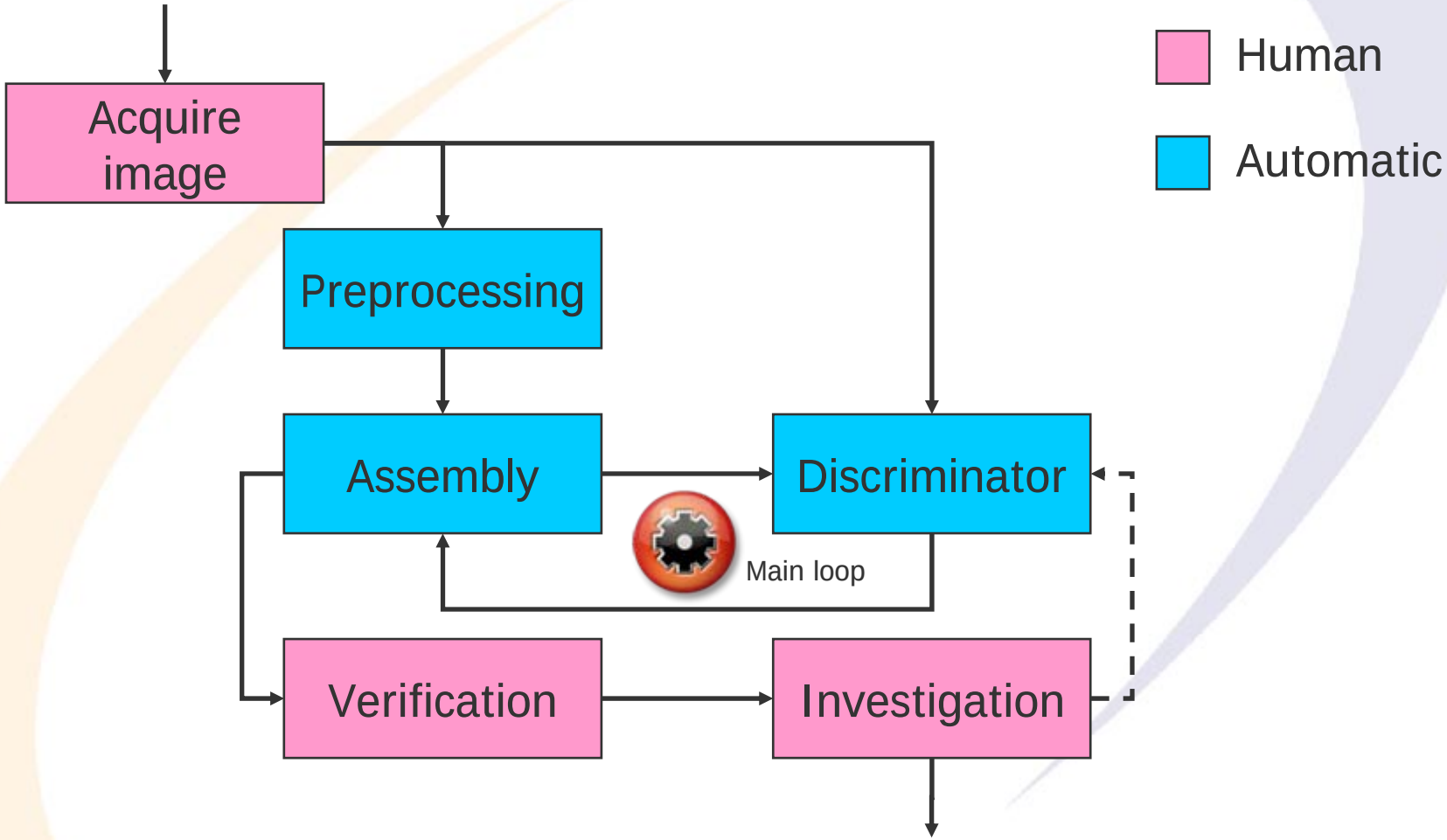
Simple file carving

- Works only for non-fragmented files
  - → Improvement: Exclude all sectors in use by other files
    - » "Real" files (still existing) and those extracted previously
    - » Other approach: Ext2/3 → The 13th block is usually an indirect pointer block (if everything was allocated in sequence)
      - – This might be verified through its internal structure/data
  - → No reordering of sectors, no intertwining allowed
    - » Reordering: Usually because of later appending to a file
      - – Or creating it and slowly writing to it (size unknown at start)
    - » Intertwining: Space was too small for the file
      - – Can happen also on creation of a full file (e.g. copy)
- Usually produces large numbers of very large files
  - → Very large as often no end marker exists
    - » Carved files contain same data/other carved files several times!
      - – First 20 kB file will be carved for a length of 10 MB and therefore contain also the next ten/twenty/… 20 KB files!
  - → Manually removing duplicates and erroneous results

Detecting the end of a file

- If a specific signature exists → Perfect!
  - → Note: Some files have header or footer signatures occurring perhaps several times within the file!
- Length of the file may be found in the header
  - → Requires detailed knowledge of the file format
    - » Especially problematic with proprietary software!
- Header signature of a new file
  - → Embedded files can be troublesome in this respect!
    - – Example: Pictures in text documents, videos in presentations, …
    - » Would mean premature termination → Careful!
- Maximum file length reached
  - → This is a fallback and very inefficient!
  - → File viewers will usually ignore added data after the end
- End of image reached (or partition/disk)

The file carving process: Overview



The file carving process: Description of human activities

- Acquire image: Acquiring a forensic duplicate from the original media in a safe way, preserving chain of custody
  - → Use write blockers and store in an appropriate format
- Verification: Making sure the result is actually a result
  - → It not only "looks" like an image/PDF/…, it actually is one!
  - → Check whether it is complete or only partially recovered
  - → Other tasks: Extraction, duplicate removal
- Investigation: Relate the result to the investigation aims
  - → Is it relevant for the case?
    - » If very relevant but incomplete, the main loop might be restarted with additional information from the manual inspection
      - – Or completely manually!
  - → Extraction of the evidential value, correlation with other evidence, documentation, etc.

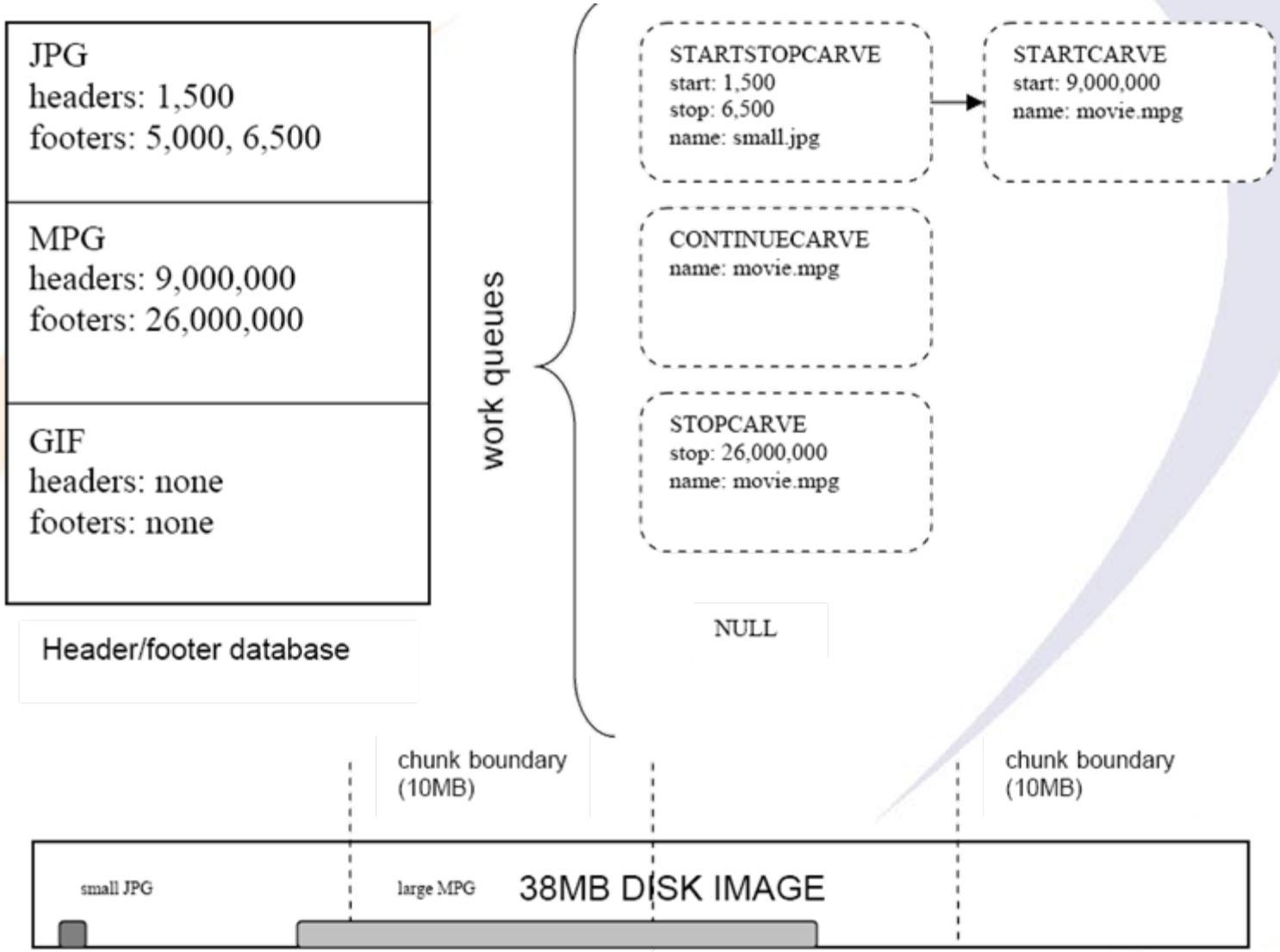
The file carving process: Description of automatic activities

- Preprocessing: Extracting information about the file
  - → Identify file type; identify start and end/length if possible
  - → Select all sectors which potentially could be part of the file
- Assembly: Generate a potential version of the file
  - → Decide which sectors to include
  - → Concatenate these sectors in a "sensible" manner
    - » According to various strategies and based on various data
  - → Note: Try "best" files first to reduce scope of searching!
- Discriminator: Check whether the result could be correct
  - → Can this file be "decompressed" or does it make "sense"?
  - → Where in the file is the erroneous position?
  - → Some parts belonging at an absolute position?
  - → Usually based on viewers/printers
    - » Difficulties: No specific error reporting, internal error recovery
    - » Is additionally problematic if the file was corrupt anyway

File carving software: Scalpel

- Reprogramming of "Foremost" for better performance and less memory requirements
  - → Limited to two sequential passes over the whole image
    - » First: Create DB of file headers and search for possible footers
      - – Only when header found and reasonably near (max. file size)
    - » In between: Matching headers and footers to create files
      - – Creates work queues for each chunk (typ. 10 MB)
    - » Second: Extract all files by working the queues for each chunk
      - – To avoid memory-to-memory copies
- Based on the "simple" approach: File headers and footers
  - → Configuration file needed, which specifies for which information to search (e.g. reducing scope to JPEG images)
  - → Produces therefore a lot of "garbage"!

File carving software: Scalpel



File carving software: Scalpel example configuration

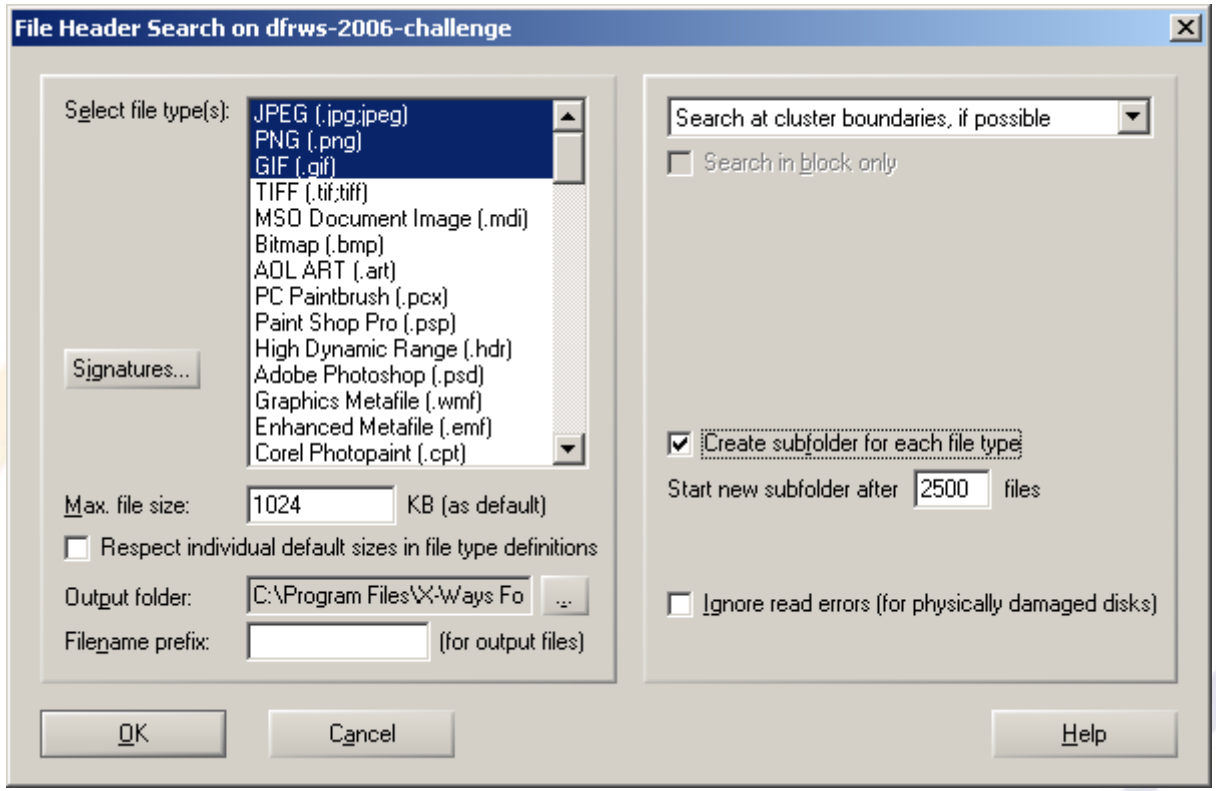
```
1    2       3            4                                  5              6
gif  y       5000000      \x47\x49\x46\x38\x37\x61           \x00\x3b
jpg  y       200000000    \xff\xd8\xff\xe0\x00\x10           \xff\xd9
png  y       20000000     \x50\x4e\x47?                      \xff\xfc\xfd\xfe
doc  y       10000000     \xd0\xcf\x11\xe0\xa1\xb1\x1a\xe1\x00\x00
                          \xd0\xcf\x11\xe0\xa1\xb1\x1a\xe1\x00\x00 NEXT
doc  y       10000000     \xd0\xcf\x11\xe0\xa1\xb1
pst  y       500000000    \x21\x42\x4e\xa5\x6f\xb5\xa6
htm  n       50000        <html                              </html>
pdf  y       5000000      %PDF                               %EOF\x0d       REVERSE
zip  y       10000000     PK\x03\x04                         \x3c\xac
```

- 1: File extension; 2: Case sensitivity of header/footer
- 3: Maximum file size in bytes; 4: Header bytes
- 5: Footer bytes (optional); 6: Footer mode (optional)
  - → NEXT → Header + all data up to and excluding the footer
  - → REVERSE → Header + all data up to last occurrence of footer within maximum file size

File carving software: X-Ways Forensic

- "File recovery by type"
  - → Requires files to be not fragmented at all
    - » Uses no optimizations → Just plain start to end/maximum size!
  - → Alignment of file start can be specified
    - » Cluster: Only possibility for files in a "good" file system
    - » Sector: Find remnants of previous file systems/partitions
    - » Byte: When no alignment is possible
      - – Backup files, embedded objects (image within text documents)
      - – Increases the number of false positives significantly
  - → Signatures are stored in an Excel file
    - » Description, extension, header, offset (of header from file start), footer, default size (override of the manually set size in the UI)
      - – Header/footer are regular expressions (GREP)
      - – Custom extensions to the list are possible
    - » Original size of jpg, gif, png, bmp, tiff, psd, cdr, avi, wav, zip, MS Word/Excel/PowerPoint, rtf, pdf, and html is extracted from file
    - » Footer is only searched up to the maximum file size

File carving software: X-Ways Forensic



→ File types should be recovered separately

» So a different maximum size can be specified!

- Manual recovery possible in addition

→ Identifying sectors + saving and concatenating them

Reducing the space requirements: CarvFS

- With huge hard disks, carving becomes more difficult
  - → Many carved files are very large, as they extend to the maximum size: the footer (no longer/did never) exists!
  - → Copying file content takes a long time
- Solution: CarvFS
  - → Virtual file system on top of FUSE (Linux userland file system)
  - → Mounting an image as a new file system
  - → Files created do not exist separately at all: They only refer to certain positions within the image!
    - » They are really only "symbolic links"
    - » Many and overlapping files → No size on disk required at all!
- Writing is not supported, only reading
- Metadata can be supplied in an additional XML file
  - → Depends on the image used, raw has none, EWF/AFF has!

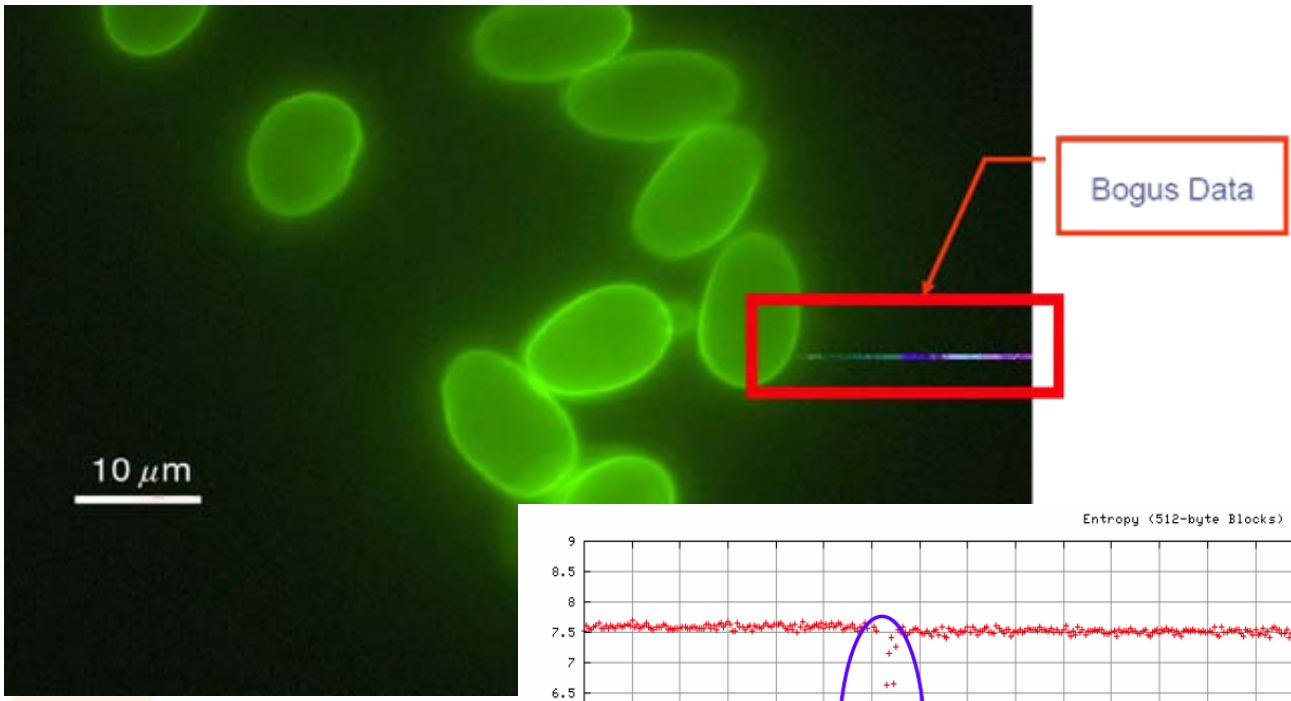
Reducing the space requirements: CarvFS

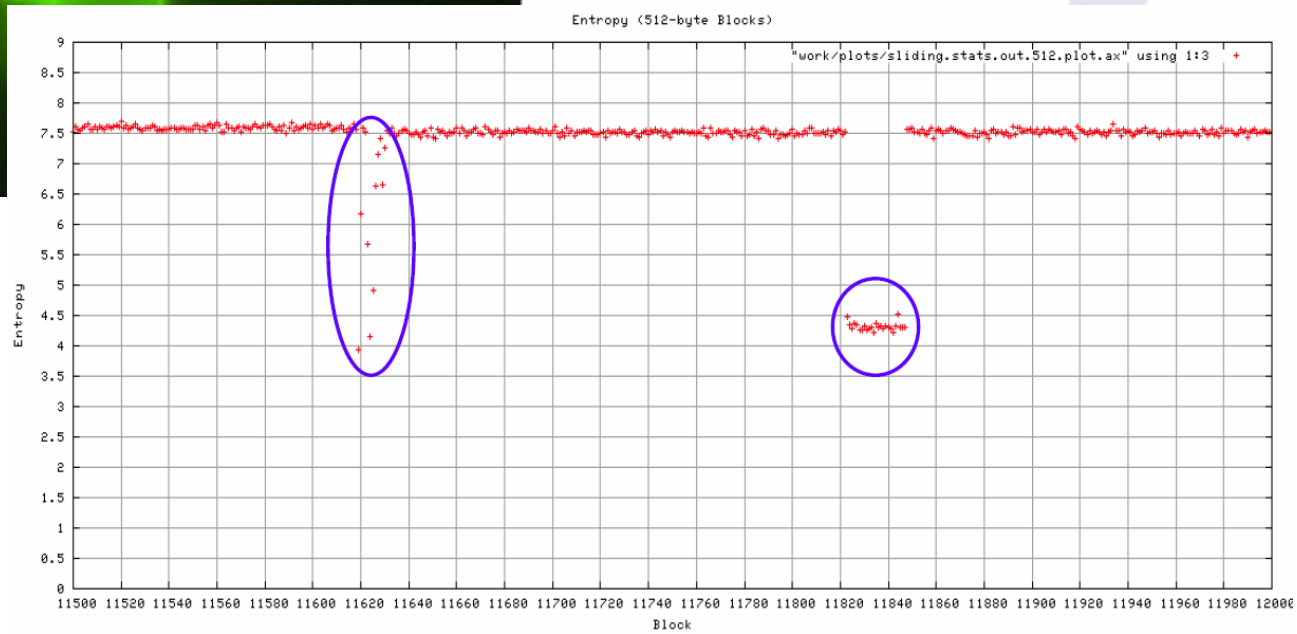
- The information on the position within the image is encoded into the name of the file
  - → Consists of several fragments
    - » Each fragment is specified by <offset>":"<size>
  - → Fragments are separated by "_"
- Note: You can open ANY file in CarvFS, even if it does not exist, but conforms to the filename specification!
  - → Example: "strings CarvFS/0:512.crv" will search the first 512 image bytes for any text strings contained and print them
- Note: CarvFS is not compatible with other forensic tools!
  - → Tools must be adapted to be able to work with CarvFS, or they will just copy out the data to a "normal" position!
    - » No "automatic" creation of the links when writing to a file!
      - – As writing is not supported at all!
    - » The tool must provide only the "coordinates" where to find a file

Sliding entropy

- Entropy = Measure of randomness
  - → Large changes in entropy will usually indicate that this sector does belong to a different file
    - » Attention: Embedded files; but these are seldom on sector boundaries → Requires a sliding window smaller than a sector!
- Average = Average value of bytes
- Sliding entropy is used to classify different data types
  - → Entropy 0-8 (8=pure random)
    - » 4-6: Text and HTML blocks
    - » 7-8: Zip and JPEG blocks
- Additional measure: ctype
  - → Counts the percentage of certain character classes
    - » Alpha(-numeric), ASCII, lower, printable, punctuation, space, …
- Not easy to fully automate
  - → Changes in entropy are best identified visually

Sliding entropy Example





Images: Smith/Monroe/Bair: Digital Forensics File Carving Advances

Semantics-based file carving

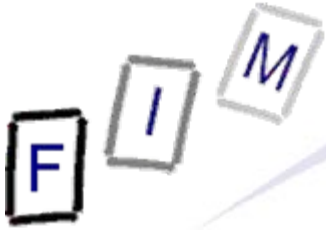
- Current research project:
  - → Carving of "text" files based on their semantic content
    - » txt, html, java, c, … Everything for direct human reading
- Basic idea: Searching in several stages
  - → Identify all potential sectors
    - » Recognizing text, programs, etc. is possible with a high certainty
      - – Programming languages: Idioms, reserved words
      - – Natural languages: Check for spaces, letters, non-letters
  - → Detect language of the file
    - » Programming language or natural language
      - – Natural language: Using stop word lists is fast and easy!
      - – Programming language: Reserved words, regular expressions
        - » Example C: include "[a-zA-Z\-_0-9]*.h"\n
  - → Hierarchy check: Nesting for programming languages (indentation) and html files (unopened/unclosed tags)
    - » Allows excluding certain sequences

Semantics-based file carving

- → Boundary check: Is the first/last word a complete word or only a fragment?
  - » Uses WordNet or custom lists
- Sorting fragments based on Google searches
  - → Build a combination of a small part of the end of a sector and a small part of the start of a sector
  - → Submit it as a fixed-string search to Google
  - → Count the results
  - → Which occurs most often (or is found at all) is the most likely combination of sectors
- Based on the idea, that texts and programs consist of common fragments which can be found in the Internet
  - → Will not work for binary files:
    - » These cannot be found by Google as easily
    - » They are much rarer and often the exact file would be required!

Conclusions

- File carving is still problematic: It takes a long time and the results are often suboptimal
  - → Large numbers of huge files, which are incomplete
- Fragmentation is not that common anymore, but still a problem even for modern file systems
  - → File carving must cope with out-of-order and missing sectors
  - → Especially problematic are files with a missing start
- Improvements possible and under development towards
  - → Requiring less memory: Verification also "in-place"
  - → Needing less IO: Fewer passes
  - → Specialisation: Working for a single file format very well
    - » Based on the specific structure, content, properties, …



Questions?

Thank you for your attention!

Conclusions

- Cohen, Michael: Advanced Carving techniques
  http://sandbox.dfrws.org/2007/cohen/Advanced_Carving.pdf
- Kloet, S. J. J: Measuring and Improving the Quality of File Carving Methods
  http://www.uitwisselplatform.nl/frs/download.php/461/thesis.pdf
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- Richard, Golden G. III, Roussev, Vassil: Scalpel: A Frugal, High Performance File Carver
  http://dfrws.org/2005/proceedings/richard_scalpel.pdf

Conclusions

- LibCarvPath and CarvFS
  http://ocfa.sourceforge.net/libcarvpath/
- Smith, Jay, Monroe, Klayton, Bair, Andy: Digital Forensics File Carving Advances
  http://www.korelogic.com/Resources/Projects/dfrws_challenge_2006/DFRWS_2006_File_Carving_Challenge.pdf