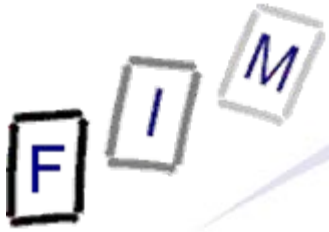



Mag. iur. Dr. techn. Michael Sonntag

# Filesystem investigation

Institute for Information Processing and
Microprocessor Technology (FIM)
Johannes Kepler University Linz, Austria

E-Mail: sonntag@fim.uni-linz.ac.at
http://www.fim.uni-linz.ac.at/staff/sonntag.htm

# Agenda

- Install the software:
  - → OSFMount
  - → Cygwin
  - → Optional (can be run from CD): WinHex, HxD
- Search for deleted files and reconstruct them
  - → WinHex: Deleted file (FAT)
  - → Reconstruct: If possible
- Discovering hidden files: Wrong extension
  - → Cygwin: "file" command
- Windows ADS
  - → LADS – Find the picture hidden in an ADS
- Timestamps
  - → WinHex: Analyze timestamps and convert them
- Running time of your Windows computer
  - → Analyze the event log

Scenario

❶

❷

❷

❸

# Images

- Source of images: http://dftt.sourceforge.net/
  - → ❶ 6-undel-fat.zip
    - » FAT image
  - → ❷ 8-jpeg-search.zip
    - » NTFS image
  - → ❸ 5-fat-daylight.zip
    - » FAT image
- Attention: Copy the files to a local disk and remove the "Read-only" attribute → Else you cannot mount them RW!
- Requirements:
  - → Operating System: Windows (XP, Vista; NT, 2K, 7: ???)
  - → Harddisk space:
    - » Scenarios: 17 MB
    - » Cygwin: A lot; approx. 700 MB!
    - » Other software: A few MB

# Software installation

- OSFMount: Mounting disk images as drives under Windows
  - → Requires Administrator access
- Install "Winhex"
  - → Not really needed; can be run directly from CD!
    - » Copy to harddisk for faster start if desired
- Install "HxD"
  - → Not really needed; can be run directly from CD!

# Software installation

- Install "Cygwin"
  - → Linux-like environment (and programs) under windows
  - → Procedure:
    - » Execute "setup.exe" and choose to install from local path
      - – Select the subdirectory starting with "ftp…" in it as install source
        - » E.g.: “E:\Software\Source”
      - – No spaces in the path of destination directory allowed!
        E.g. **not** C:\Program Files\...
    - » Change selection to "install" on the "All" selection
      - – Click on the "circular arrows" icons repeatedly (once should suffice)
  - → Add the binary directory to the path
    - » XP: Control panel – System – Advanced – Environment Variables → Add the complete path to the user variables, e.g. add ";C:\Cygwin\bin“ to the end
    - » Win 7: Control panel – System and Security – System – Advanced System Settings – Environment Variables

# Search for deleted files: FAT

- Find and recover the deleted files in image ❶!
- Your task:
  - → Find out, which files did at some time exist in the image
    - » Recovery through WinHex/HxD!
      - – Manual recovery in WinHex not possible due to evaluation version limitations
  - → Recover these files
    - » Check their MD5 values
- Document your actions through a log and screen shots!

- Hints:
  - → FAT1 starts at offset 0x1000, FAT2 (=copy) at 0x4000
  - → Root directory is at offset 0x7000

# Search for deleted files: FAT

- MD5 table of correctly recovered files
  - → Filename File size MD5 value
  - → \SING.DAT 780 `59B20779F69FF9F0AC5FCD2C38835A79`
  - → \MULT1.DAT 3801 `FFD27BD782BDCE67750B6B9EE069D2EF`
  - → \FRAG1.DAT 1584 `7A3BC5B763BEF201202108F4BA128149`
  - → \FRAG2.DAT 3873 `0E80AB84EF0087E60DFC67B88A1CF13E`
  - → \DIR1\
  - → MULT2.DAT 1715 `59CF0E9CD107BC1E75AFB7374F6E05BB`
  - → DIR2\
  - → FRAG3.DAT 2027 `21121699487F3FBBDB9A4B3391B6D3E0`

# Search for deleted files: FAT

- Mount the image ❶ as readonly (6-fat-undel.dd)
- Look at the image directly (cmd.exe)
  - → There is not a single file there!
- Examine it using a Hex editor
  - → Find the FAT and the root directory (see also later)
  - → Root dir: Starts at offset 0x7000 (=sector 56)
    - » Note: The first directory entry is not a file, but the volume label!
- Root dir content:
  - → ?RAG1.DAT, ?RAG2.DAT, ?ING.DAT, ?ULT1.DAT, ?YSTEM~1 ("System Volume Information"; long filename)
    - » 0xE5 → This file has been deleted
  - → ?IR1: Deleted directory
    - » Difference file vs. directory? Byte 0x0B, Bit 4 (here: 0x10)!

# Search for deleted files: FAT

- Manual undelete of ?ING.DAT
  - → Overwrite first byte (0xE5) with something else (e.g. 0x53 = S)
    - » Note: You have to change into edit mode with F6!
    - » But writing to the disk does not work in the evaluation version!
      - – Default edit mode gives an error message, but in-place mode just silently ignores all changes you make!
  - → Right-click on the file and then "Recover/Copy…"
  - → Copy the files to your hard disk and calculate their MD5 sum
    - – Example: "md5sum _ING.DAT"
    - » Note, that the MD5 for ?ING.DAT and ?ULT1.DAT are correct, but those for ?RAG1.DAT and ?RAG2.DAT are not
    - » Why? Examine the FAT table at offset 0x1000 (or 0x4000)!
    - » The FAT has been completely cleared, except for the first sector
      - – This is the sector of the root directory!
  - → Automatic undelete has therefore the problem, that it cannot know which sectors belong to a file if fragmentation occurs!
    - » File carving needed!

# Search for deleted files: FAT

- → Result: Start at first (=known) sector and copy consecutive number of bytes till the file size has been reached
- → Possible chance at detection (but not solution!): The sector is marked as "in use" by another directory entry
  - » However, this is marked as deleted as well, so which one was the later one cannot really be determined either!
    - – MAC dates might help here to some degree

- Deleted directory: Only the directory is marked as deleted
  - → The files/directory inside are only implicitly deleted!
  - → Their first character still exists: MULT2.DAT and subdir DIR2
  - → \DIR1\DIR2: FRAG3.DAT
  - → MULT2.DAT can be recovered, FRAG3.DAT is again a fragmented file and cannot be recovered
    - » Although extracted without **any** warning or error message!

# Discovering hidden files: Wrong extensions

- Find out, which of all the files in image ❷ are jpg pictures!
- Your task:
  - → Collect all files, except those in archives
    - » How many are these?
  - → Identify their file type
    - » Do this manually (Winhex/HxD)
      - – Check first in the internet: How to recognize a JPG file
    - » Use the command "file"
      - – Inspect the "magic" file and find the description for JPG files
    - » Use command "strings" (file1.jpg, file4.jpg, file12.doc, cmd.exe)
  - → Identify the file type of the archives
- Document your actions through a log and screen shots!

# Wrong extensions: Exemplary solution – Manual check

- Mount the image ❷ as readonly (8-jpeg-search.dd)
- Collect all files
  - → alloc\file1.jpg, alloc\file2.dat, \invalid\file3.jpg, \invalid\file4.jpg, \invalid\file5.rtf, misc\file11.dat, misc\file12.doc, misc\file13.dll
  - → In total 8 files (+3 archives)
- Search the Internet for recognizing JPEG files
  - → E.g. search Google for "JPEG magic number"
    - » See http://en.wikipedia.org/wiki/Magic_number_(programming)
    - » JPEG start with 0xFFD8 and end with 0xFFD9
      - – Most (JPEG/JFIF type) also contain "JFIF\0"!
- Identify files manually
  - → Open alloc\file1.jpg in Winhex
    - » Both start and end match, and "JFIF" is found at offset 0x06
  - → This also applies to alloc\file2.dat → Wrong extension!

# Wrong extensions: Exemplary solution – Manual check

- → invalid\file3.jpg has a different start (0x4865) and end (0x300A)
- → invalid\file4.jpg claims to be a JPEG, but has only a header
  - » The footer is 0x9F32; additionally there is no "JFIF"
    - – Only "JF", and that at index 0x02AB90!
- → invalid\file5.rtf has neither header nor footer and no "JFIF"
  - » But signature occurs several times within, e.g. 0x2CF3, 0x4094!
  - » Only "JF" at 0x013062 (no "JFI" or "JFIF"!)
- → misc\file11.dat has a wrong header, but a correct footer
  - » Additionally, "JFIF" occurs at 0x062A
  - » At 0x0624 there is the correct header signature
  - » This could be a JPEG with some other data at the beginning
    - – Extract it with WinHex (in 2 parts, e.g. to 0x31FFF; eval. limit)
    - – Concatenate with "copy /b part1.bin + part2.bin file11.jpg"
  - » We have recovered a new picture ("I Am Picture #8")!

# Wrong extensions: Exemplary solution – Manual check

- misc\file12.doc is similar to file11.dat, but the end of the picture is not the end of the file
  - Do the same as above
  - Actually, this is a valid MS Word document with an embedded JPEG; these are not necessarily always stored as "plain“ data!
  - Extract from 0x1348 until 0x1C26C (inclusive)
    - 0x1348-0xFFFF and 0x010000-0x1C26C; Concatenate
  - We have recovered "I Am Picture #9"!
- misc\file13.dll: Header and footer wrong, no "JFIF"
  - This is no picture!
  - It looks more like random data

# Wrong extensions: Exemplary solution – "file" command

- The file command uses a table of "magic values" to identify file types according to their content
  - → These rules can be very simple, but also complex
- Where is the file: %CYGWIN%\usr\share\misc\magic.mgc
  - → JPEG now in separate file (here a compiled version!)
    - » Note: "JFIF" occurs already before, but those are movie files!
  - → As can be seen, only the start of the file is checked!
    - » Starts with 0xFFD8
    - » At exactly the position 0x06 the string "JFIF" must occur
      - – The ">" is a continuation marker, **not** an index modifier!
- Identify file types:
  - → alloc/file1.jpg: JPEG image data, JFIF standard 1.01
  - → alloc/file2.dat: JPEG image data, JFIF standard 1.01
  - → /invalid/file3.jpg: ASCII English text
    - » Actually, the file only starts with ASCII English text. But as only the start is checked, the rest is ignored!

# Wrong extensions: Exemplary solution – "file" command

- \invalid\file4.jpg: JPEG image data
  - » Note: No "JFIF" and "version ?.?"!
    - – Identified, as only the (correct) header is checked, but not the footer
    - – The missing "JFIF" should be a warning sign here!
- \invalid\file5.rtf: data
  - » Could not be identified; actually it is just random data
- misc\file11.dat: data
  - » As only the start is checked, the picture later on is **not** found!
- misc\file12.doc: CDF V2 Document
  - » This is a "Microsoft Office Document"
    - – The type of Microsoft office files is often hard to identify because of the complex file format
      - » Actually a kind of archive with several streams
- misc\file13.dll: data
  - » Just random data, correctly identified

# Wrong extensions: Exemplary solution – "strings" command

- Only as an example: The "strings" command
  - → More useful for investigating executables
    - » What text do they contain
    - » If a debug version → what methods do they call, messages etc.
- Examine alloc\file1.jpg
  - → strings file1.jpg | more
    - » All strings, first one is "JFIF"
  - → strings file1.jpg | grep "JFIF"
    - » Select only those lines containing the specific string
- Examine invalid\file4.jpg
  - → strings file4.jpg | grep "JFIF"
    - » Returns nothing → no JPEG
      - – Actually, just not a JPEG/JFIF!

# Wrong extensions: Exemplary solution – "strings" command

- Examine misc\file12.doc
  - → Finds "JFIF" very early, but not as the first string
  - → The end is more interesting: The document properties!
    - » We can find out that some "Brian Carrier" is somehow involved with this document
      - – Detailed investigation: This is the author (of document and image)
    - » We can also see that it was created by Microsoft Word 10.1
      - – What version is this really? From when is it?
        - » MS MacWord 10.1 (=“Office X”) from 2001
- Examine %SYSTEMROOT%\system32\cmd.exe
  - → Lots of Windows functions
    - » E.g. MessageBeep, CopyFileExW, RegEnumKeyW, _wcslwr
  - → At least one message "CMD Internal Error %s"
  - → Some "ASCII art" (probably icon information)

# Wrong extensions: Exemplary solution – Archives

- Check the file type of the archives with the "file" command
  - → file8.zip: Zip archive data, at least v2.0 to extract
    - » "unzip file8.zip –d C:\temp"
      - – file8.jpg + random8.dat (some random data)
    - » file8.jpg is "I Am Picture #5"
  - → file9.boo: Zip archive data, at least v2.0 to extract
    - » Unzip as before → file9.jpg + random9.dat
    - » file9.jpg is "I Am picture #6"
  - → file10.tar.gz: gzip compressed data, from Unix
    - » "file –z file10.tar.gz" → Identifies a TAR inside a ZIP
    - » "gzip –d file10.tar.gz –c > C:\temp\file10.tar"
  - → file10.tar: POSIX tar archive (GNU)
      - – A file archive (several files; not compressed!)
    - » "tar –xvf file10.tar"
      - – file10.jpg + random10.dat (some random data)
    - » file10.jpg is "I Am Picture #7"

# Search for deleted files: Bonus example - NTFS

- Search for deleted files in this image
- Recover them if possible
  - → In del1 a deleted JPEG can be recovered (file6.jpg)
  - → In del2 another file could theoretically be recovered completely (file7.hmm)
    - » Not actually because of the WinHex evaluation version size limit!
    - » Or recover it manually in two parts and combine them
- Note that this is not a FAT, but a NTFS volume!

# Windows ADS

- Find the hidden picture!
- In the image ❷ there is an additional picture hidden
  - → This is located within an alternate data stream
- Your task:
  - → Find the location of the hidden picture
  - → Extract the picture into a separate "normal" file
  - → Add the picture to another file and to a directory
    - » Not "into" the directory, but to the directory entry itself!
    - » Name the ADS "new*picture"
      - – Could you create a normal file with this name?
- Document your actions through a log and screen shots!

# Windows ADS: Exemplary solution

- Mount the image ❷ as **read-write** (8-jpeg-search.dd)
- Run lads for every directory
  - → Or use the parameter "/s" on the root directory
- Look at the result: The file "**?**:\misc\file13.dll" contains an ADS with the name "here"
  - → "**?**:\misc\file13.dll:here"
- Extract the ADS through "more"
  - → "more < **?**:\misc\file13.dll:here >here.jpg"
  - → Examine the file: Is it really a picture?
  - → Check the MD5: It should be 9b787e63e3b64562730c5aecaab1e1f8!
    - » The result is different! Why?
  - → Open the file in Winhex and compare it to another JPEG file from the same drive
    - » It seems, that "more" does some textual translation, outputting 0x0D0A instead of 0x00 (translation to plain text!)

# Windows ADS: Exemplary solution

- Extract through "cp" (Cygwin!)
  - → "cp **?**:\misc\file13.dll:here here.jpg“
    - » **NOT WORKING** with current cygwin version anymore!
  - → Check the file with a hex editor: Is it a picture? Yes!
  - → Calculate the MD5 value and check it
    - » Now it is OK!
- View the picture: Just open it (double-click) or use Paint
  - → It shows a green puzzle tile and the text "I Am Picture #10"

# Timestamps

- Find out when the two files in image ❸ were actually created
- Your task:
  - → Check the date through the Windows command line
    - » Would changing the local time zone influence the output?
    - » Compare this to your OS drive (hint: FAT ⇔ NTFS/EXT3!)
  - → Find out where the creation time is located on the disk
    - » Don't use the WinHex UI; first think and calculate, then verify!
  - → Manually calculate the creation time from the hex values
    - » Search the internet for the exact format
  - → Use DCode to decode the creation time
  - → When were the files created in UTC?
- Document your actions through a log and screen shots!

# Timestamps: Exemplary solution

- Mount the image ❸ as readonly (daylight.dd)
- Check dates through command line
  - → Result:
    - » Winter.txt: 1.1.2004 14:00
    - » Summer.txt: 1.6.2004 15:00
  - → Changing the local time zone would not change the output!
    - » FAT stores date/time according to the local time of the computer at the moment the action occurs
    - » Therefore it is not "recalculated" according to the local time zone
      - – As for example NTFS dates are: These are stored as UTC!
      - – File shows 14:26 in TZ Austria (+1), but 13:26 in TZ London (=UTC)!
- Where is the FAT on a FAT-disk?
  - → Offset 0x0e in first sector: Number of reserved sectors (=1)
  - → FAT therefore starts immediately after the boot sector
    - » This is address 0x0200 (1 sector = 512 bytes)

# Timestamps: Exemplary solution

- → Root directory starts immediately after the FAT-copy
  - » Length of FAT: Offset 0x16 = 9
  - » Boot + FAT1 + FAT2 = 1+9+9 = 19 sectors = 0x2600
- → One directory entry = 32 bytes
- → Creation time: 0x0D-0x11
  - » Modification: 0x16-0x19 (2s resolution only)
  - » Access: 0x12-0x13 (date only)

- Manual calculation from the hex values
  - » See http://en.wikipedia.org/wiki/File_Allocation_Table for details
- → Value: 0x8600702130
  - » Fine time: 0x86 = 134*100ms = 1.34 s
  - » Time: 0x7000 = 14 hours, 0 minutes, 0*2 seconds
    - – Little endian, therefore to be converted as 0x7000 and not the 0x0070 as found on the disk!
  - » Date: 0x3021 = 24+1980 years, month 1 (=January), day 1
  - » Result: 1.1.2004, 14:00:01.34

# Timestamps: Exemplary solution

- Use DCode to decode the date and time
  - → Note: DCode only can convert 4-Byte times!
  - → Use "MS-DOS: 32 bit Hex Value"
  - → To enter: 00702130 (omit first byte; little endian!)
  - → Result: 1/Jan/2004 14:0:0 Local
- When were the files created in UTC?
  - → This we cannot say, as the date/time is always stored in local time only. Unless we know the time zone where the file was created, we simply cannot determine it!

# Windows Startup/Shutdown time

- Investigate your own computer:
  - → When was it turned on and off during the last week?
    - » Investigate in the Internet which events are logged when!
  - → Draw a timeline to visualize your results!

# Windows Startup/Shutdown time: Exemplary solution

- The Startup/shutdown time is logged in the event log
  - → These are part of the "System" log
  - → See http://support.microsoft.com/kb/196452
  - → Date and time of the event are logged as well
    - » Note: Local time!
- Event-IDs:
  - → 6009: Startup (OS version, …)
  - → 6005: Event log service started
  - → …
  - → 6006: Clean shutdown/Event log service stopped
  - → 6008: Dirty shutdown
    - » Unexpected, e.g. through power failure

# Windows Startup/Shutdown time: Exemplary solution

- To ease the gathering, use "View – Filter…" to only show events with specific IDs
- Exemplary results:
  - → No 6008 events!

| Type | Date | Time | Source | Category | Event |
|---|---|---|---|---|---|
| Information | 14.01.2008 | 07:39:35 | eventlog | None | 6009 |
| Information | 11.01.2008 | 07:42:02 | eventlog | None | 6009 |
| Information | 10.01.2008 | 07:42:36 | eventlog | None | 6009 |
| Information | 09.01.2008 | 07:52:19 | eventlog | None | 6009 |
| Information | 08.01.2008 | 07:52:27 | eventlog | None | 6009 |
| Information | 07.01.2008 | 07:48:25 | eventlog | None | 6009 |
| Information | 04.01.2008 | 08:44:11 | eventlog | None | 6009 |
| Information | 03.01.2008 | 08:46:04 | eventlog | None | 6009 |
| Information | 02.01.2008 | 08:41:38 | eventlog | None | 6009 |
| Information | 21.12.2007 | 08:38:17 | eventlog | None | 6009 |
| Information | 20.12.2007 | 08:42:55 | eventlog | None | 6009 |

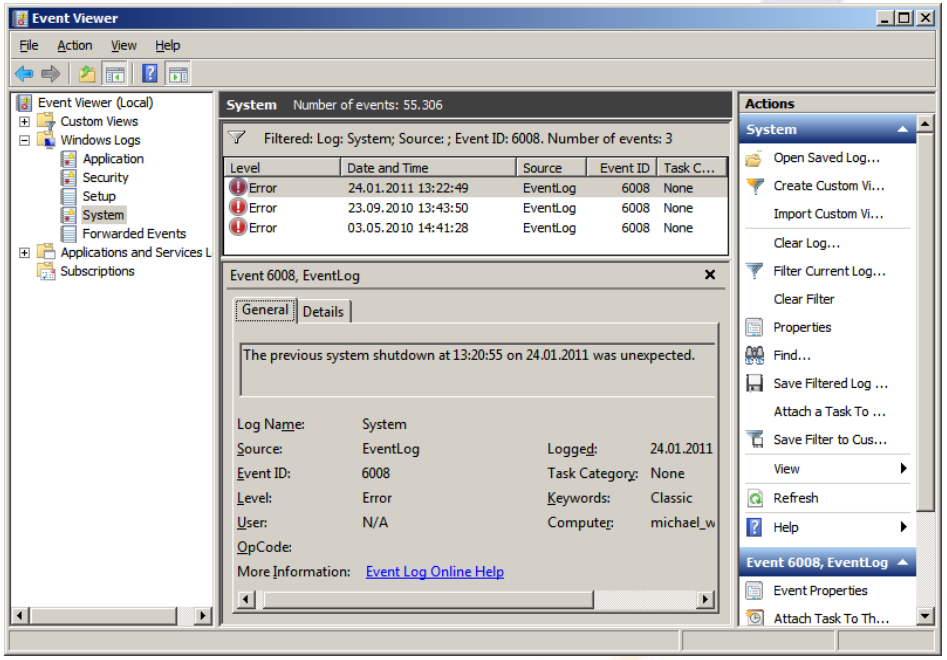
| Type | Date | Time | Source | Category | Event |
|---|---|---|---|---|---|
| Information | 11.01.2008 | 18:00:31 | eventlog | None | 6006 |
| Information | 10.01.2008 | 17:37:32 | eventlog | None | 6006 |
| Information | 09.01.2008 | 20:11:26 | eventlog | None | 6006 |
| Information | 09.01.2008 | 07:51:18 | eventlog | None | 6006 |
| Information | 07.01.2008 | 17:11:09 | eventlog | None | 6006 |
| Information | 04.01.2008 | 17:13:34 | eventlog | None | 6006 |
| Information | 03.01.2008 | 17:05:44 | eventlog | None | 6006 |
| Information | 02.01.2008 | 16:20:33 | eventlog | None | 6006 |
| Information | 19.12.2007 | 22:54:01 | eventlog | None | 6006 |

# Windows Startup/Shutdown time: Exemplary solution

- Result:
  - → Monday 7.1.2008: 7:48-17:11
  - → Tuesday 8.1.2008: 7:52- 7:51 (next day!)
  - → Wednesday 9.1.2008: 7:52-20:11
  - → Thursday 10.1.2008: 7:42-17:37
  - → Friday 11.1.2008: 7:42-18:00
- Extraordinary period on night of 8.1. to 9.1.
  - → Further investigation: Some updates occurred at 5 o'clock in the night, so the computer was actually running
  - → It seems, it was just not turned off
  - → Whether it was in actual use cannot be decided!
    - » But as no other events occurred during that time, this is unlikely
      - – Windows update is automatic → No user needed to be there!

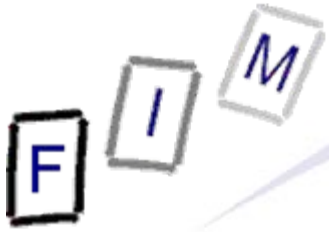
# Windows Startup/Shutdown time: Windows 7

- Control Panel – System and Security - Administrative tools
  - → Select System log click under actions “Filter current log…”
  - → Enter the ID “6008” in the form, or write the filter manually:
    - » <QueryList>
      <Query Id="0" Path="System">
      <Select Path="System">*[System[(EventID=6008)]]</Select>
      </Query>
      </QueryList>
  - → Events can also be shown as native XML



# Conclusions

- Undelete is quite simple on FAT
  - → But complex/impossible on NTFS/EXT3!
  - → "Plain text" search will still work unless actually overwritten
- Hiding files is quite simple: Wrong extensions and ADS
  - → Found only with good knowledge and additional tools
    - » But **VERY** difficult to **REALLY** hide information!
- Even with very simple means a lot of information can be extracted, if it is exactly known where to look for it
  - → But also its limitations must be known!
- Timestamps (or timing issues) are an important aspect for every forensic investigation
  - → The time zone is very important there
    - » Is the data stored in local or UTC (or …) time?
    - » What is the difference to UTC now (and what was it then?)




# Questions?

**Thank you for your attention!**