Topic 1 - Digital Files

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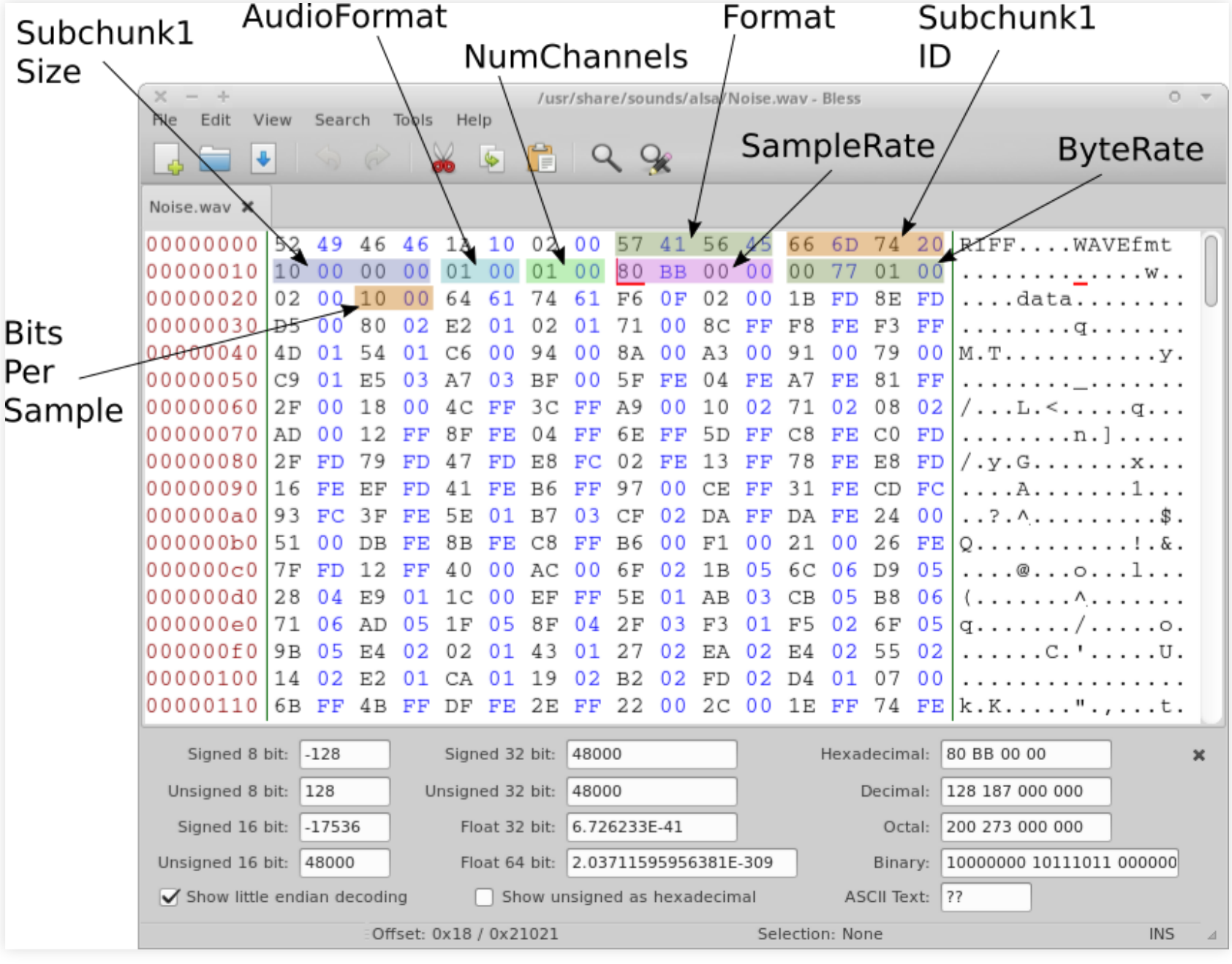
File Format Considerations

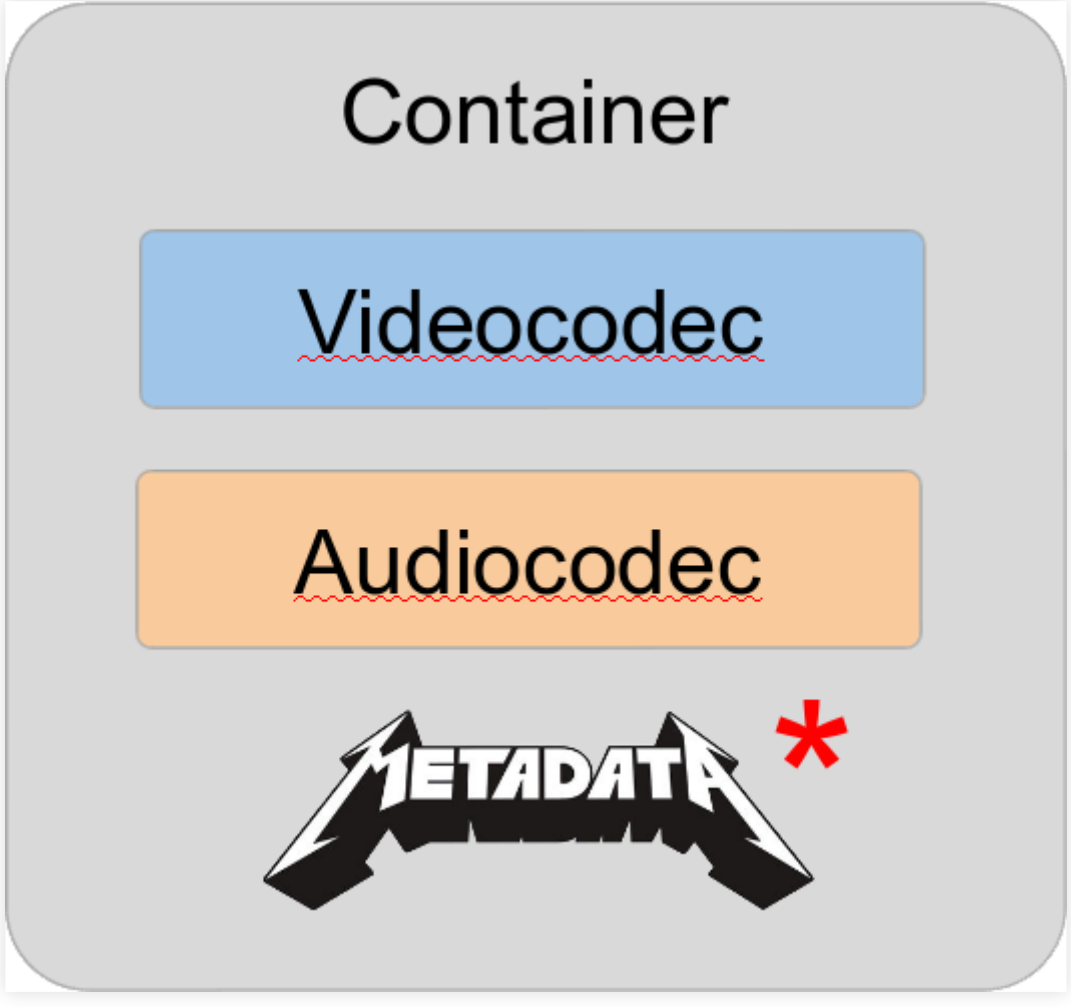
The Goal

* Best quality * Preserve original properties * Last forever * Lowest size * Fast and easy to open/use * +cherries & ice cream on top * ...

Data Structure


Subchunk1 Size
AudioFormat
NumChannels
Format
Subchunk1 ID
SampleRate
ByteRate
Bits Per Sample
/usr/share/sounds/alsa/Noise.wav - Bless
File Edit View Search Tools Help
Noise.wav
00000000 52 49 46 46 1a 10 02 00 57 41 56 45 66 6D 74 20 RIFF....WAVEfmt
00000010 10 00 00 00 01 00 01 00 80 BB 00 00 00 77 01 00 .....w..
00000020 02 00 10 00 64 61 74 61 F6 0F 02 00 1B FD 8E FD ....data.....
00000030 B5 00 80 02 E2 01 02 01 71 00 8C FF F8 FE F3 FF ....q.....
00000040 4D 01 54 01 C6 00 94 00 8A 00 A3 00 91 00 79 00 M.T.....y.
00000050 C9 01 E5 03 A7 03 BF 00 5F FE 04 FE A7 FE 81 FF ....._.....
00000060 2F 00 18 00 4C FF 3C FF A9 00 10 02 71 02 08 02 /...L.<.....q...
00000070 AD 00 12 FF 8F FE 04 FF 6E FF 5D FF C8 FE C0 FD ....n.]....
00000080 2F FD 79 FD 47 FD E8 FC 02 FE 13 FF 78 FE E8 FD /.y.G.....x...
00000090 16 FE EF FD 41 FE B6 FF 97 00 CE FF 31 FE CD FC ....A.....1...
000000a0 93 FC 3F FE 5E 01 B7 03 CF 02 DA FF DA FE 24 00 ..?.^.....$.
000000b0 51 00 DB FE 8B FE C8 FF B6 00 F1 00 21 00 26 FE Q.....!.&.
000000c0 7F FD 12 FF 40 00 AC 00 6F 02 1B 05 6C 06 D9 05 ....@...o...l...
000000d0 28 04 E9 01 1C 00 EF FF 5E 01 AB 03 CB 05 B8 06 (.....^.....
000000e0 71 06 AD 05 1F 05 8F 04 2F 03 F3 01 F5 02 6F 05 q.....o.
000000f0 9B 05 E4 02 02 01 43 01 27 02 EA 02 E4 02 55 02 .....C.'.....U.
00000100 14 02 E2 01 CA 01 19 02 B2 02 FD 02 D4 01 07 00 .....
00000110 6B FF 4B FF DF FE 2E FF 22 00 2C 00 1E FF 74 FE k.K.....",...t.
Signed 8 bit: -128
Unsigned 8 bit: 128
Signed 16 bit: -17536
Unsigned 16 bit: 48000
Signed 32 bit: 48000
Unsigned 32 bit: 48000
Float 32 bit: 6.726233E-41
Float 64 bit: 2.03711595956381E-309
Hexadecimal: 80 BB 00 00
Decimal: 128 187 000 000
Octal: 200 273 000 000
Binary: 10000000 10111011 000000
ASCII Text: ??
Show little endian decoding
Show unsigned as hexadecimal
Offset: 0x18 / 0x21021
Selection: None
INS

Digital Video Trinity

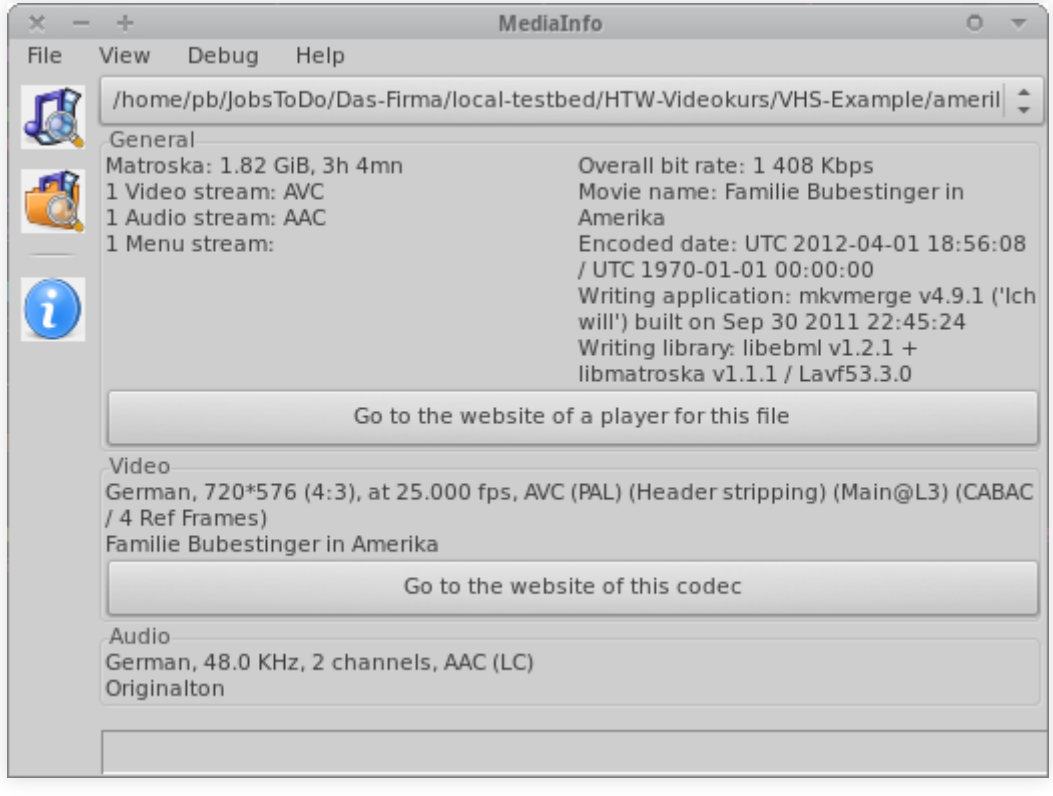


Speaker notes

A/V media files: "The" format of video files usually consists of 3 different formats:

- Container
- Video
- Audio

Remember?


MediaInfo
File
View
Debug
Help
/home/pb/JobsToDo/Das-Firma/local-testbed/HTW-Videokurs/VHS-Example/ameril
General
Matroska: 1.82 GiB, 3h 4mn
1 Video stream: AVC
1 Audio stream: AAC
1 Menu stream:
Overall bit rate: 1 408 Kbps
Movie name: Familie Bubestinger in Amerika
Encoded date: UTC 2012-04-01 18:56:08 / UTC 1970-01-01 00:00:00
Writing application: mkvmerge v4.9.1 ('Ich will') built on Sep 30 2011 22:45:24
Writing library: libebml v1.2.1 + libmatroska v1.1.1 / Lavf53.3.0
Go to the website of a player for this file
Video
German, 720*576 (4:3), at 25.000 fps, AVC (PAL) (Header stripping) (Main@L3) (CABAC / 4 Ref Frames)
Familie Bubestinger in Amerika
Go to the website of this codec
Audio
German, 48.0 KHz, 2 channels, AAC (LC)
Originalton

Characteristics

Image

	File 1	File 2	File 3
Format	TIFF 6.0	TIFF 6.0	TIFF 4.0
Colorspace	RGB	CMYK	Grayscale
DPI	600 dpi	150 dpi	150 dpi
Resolution	4328 x 2979px	1024 x 768	1024 x 768

Characteristics

Audiovisual

	File 1	File 2	File 3
Format	MOV	MOV	MOV
Resolution	720 x 576px	1920 x 1080	640 x 480
FPS	25	24	29.97
Samplerate	48 kHz	48 kHz	44.1 kHz
Channels	Stereo	Surround 5.1	Mono

Data rate / Filesize

Type	Duration	Bitrate	Filesize
Video	1 hour	210 Mb/s	92 GB
		50 Mb/s	22 GB
		25 Mb/s	11 GB
		1,5 Mb/s	1 GB
Audio	1 hour	4,6 Mb/s	2 GB
		128 kb/s	56 MB

Different Formats, different use cases

- Preservation
- Mezzanine
- Access

Speaker notes

These are the 3 typical use cases for files. Sometimes all 3 can be satisfied by a single format, sometimes not.

We'll see on the next slide what these are meant for.

Different Formats, different use cases

- **Preservation:** Stand the test of time.
  Highest original quality.
- **Mezzanine:** For daily work.
  High quality.
- **Access** For quick and easy access.
  Quality not necessarily best/high.

Examples: Video

- **Preservation:**

* Uncompressed * FFV1 * J2K-lossless * ...

- **Mezzanine:**

* ProRes * H.264 * DVCPRO50 * ...

- **Access:**

* MP4 * WebM * DVD * BluRay * ...

Speaker notes

I've intentionally used fuzzy wording for access formats, since it better depicts the perception and wording used in daily life.

For Preservation and Mezzanine, I've left out audio- and container-formats, since it would unnecessarily complicate the slide.

Later in this session, we'll get to how to select properties for these use cases, which helps to decide which format to use for which case.

Size (still) matters

Type	Duration	Bitrate	Filesize	Usage
Video	1 hour	210 Mb/s	92 GB	Preservation
		50 Mb/s	22 GB	Preservation
		25 Mb/s	11 GB	Preservation / Mezzanine
		1,5 Mb/s	1 GB	Access
Audio	1 hour	4,6 Mb/s	2 GB	Preservation
		128 kb/s	56 MB	Access

Data rate = Bitrate

- Mbps / 8 = MB / second
- MB/s * 60 = MB / minute
- MB/min * 60 = MB / hour

Speaker notes

If you know the bitrate, you can calculate the size of your files, by multiplying the bitrate by the runtime duration (time).

A fixed bitrate however is only available for:

- constant bitrate (lossy) compression.
- uncompressed.

For lossy compression, bitrate is an encoding parameter, but for uncompressed we'll show later in this session how to calculate the size.

For lossless or variable bitrate, the exact size cannot be pre-calculated - only estimated. The actual size can still vary, since the size of these kind of encodings greatly depends on the content being encoded. Rule of thumb: Less motion = smaller size and vice versa. Noise make files larger.

Significant properties

- Depends on media type.
- Examples for A/V:
  - resolution
  - framerate
  - aspect ratio
  - colorspace
  - subsampling
  - ...

More: FADGI Significant Properties for Digital Video - DRAFT

Speaker notes

Definition fuzziness in the preservation community: Some say "Significant" are the properties that must be maintained as-is and kind of "must never change", whereas others define it as "should be aware of and decided how to deal with them".

Further properties: * scan type (interlaced / progressive) * field order * color information * ...

Significant properties

Image?

Speaker notes

Image: * Same as for single video frame * But usually different colorspaces

Significant properties

Audio?

Speaker notes

Audio (uncompressed): * Samplerate * bit-depth per sample * Channels / Channel layout * Endianess? (debate)

Lossy, Lossless, Uncompressed?

How it affects quality and preservation.

Speaker notes

It's not only technical, but highly political... Including Fear, Uncertainty and Doubt (FUD).

Lossy

Speaker notes

Of course this image is exaggerated, but it shows pretty well what lossy compression is and what artefacts a typical MPEG-like compression algorithm produces.

btw: This is a snapshot image of the highest-quality version of the video on the original website (around 2009).

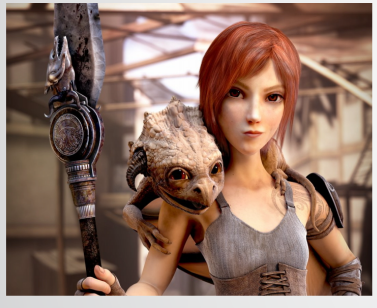
Generation Loss

Generation Loss Comparison

(color/contrast increased for better visibility)

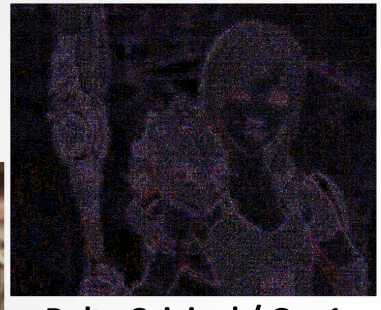
AUDIO SOLUTIONS

Original

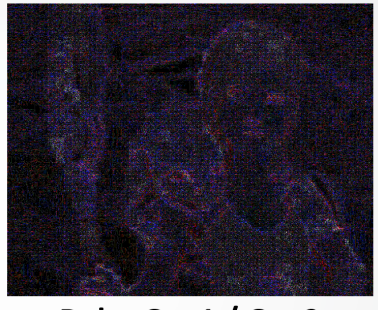


RAW (YUV422)

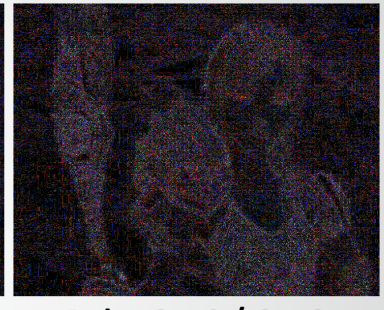
IMX50 D10 (YUV422)



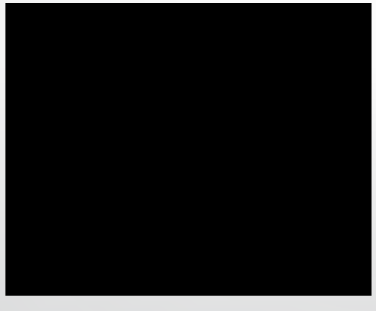
DVCPro50 (YUV422)



IMX50 D10 (YUV422)

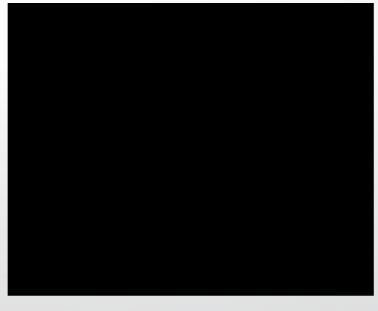


Delta Original / Gen1



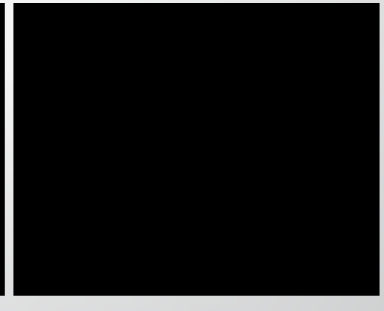
FFv1 (YUV422)

Delta Gen1 / Gen2



FFv1 (YUV422)

Delta Gen2 / Gen3



FFv1 (YUV422)

Speaker notes

Here's an example where one can see the difference between each encoded version in popular broadcast codecs.

Since it's almost certain that there's not "evergreen format", any format will sooner or later have to be migrated to another one. The longer an item is preserved, the more often it will encour such a format change (transcoding). Therefore, generation loss should be considered.

Also: Usage of archive material: What happens if you hand out your material to an editor, say on DVD or a mezzanine format? The editor then edits and exports to another format, the broadcaster or cinema then to another? ...and in the end this work is then also converted to an access format.

And theeeen, years later that access copy is used as a source for a documentary or online edit.

How many generation losses accumulate here? How could they be reduced?

Generally: please try to avoid unnecessary generation losses. Why not? :)

Lossless

> *"It's like ZIP for film!"*

- No generation loss
- Way larger than lossy
- Smaller than uncompressed

Uncompressed

- No generation loss
- Dead simple (=preserves well)
- The largest possible version
- There's *more* than just 1 "uncompressed"

Uncompressed - Think of it as:

1px RGB Image:

```
RRR GGG BBB AAA
```

1px YUV Image:

```
YYY UUU VVV
```

1 sample audio:

```
LLLLLLLL RRRRRRRR
```

Speaker notes

Image: 8 bits-per-component = 3 Bytes (therefore 3 characters here per component):

- Red, Green, Blue
- YUV
- Alpha

Audio: 8 bits per sample, 2 channels:

- Left
- Right

All you need to know is (somewhat):

- Color model
- Width (=line length)
- Sample size
- Channels

Uncompressed Image

- Width(px) x Height(px)
- x Bits-Per-Pixel(bpp)
- x FPS
- / 8 = **1 second (in Byte)**

Uncompressed Audio

- Samplerate x bit-depth
- x channels (even if silence!)
- / 8 = **1 second (in Byte)**

Speaker notes

Exercise:

- How large is an 8bpc SD PAL minute - with 4 channels audio at SDI standard (48kHz/16bit)?
- Or a 2k 16bpc(!) scan (including 6 channels audio at 48kHz/24bit)?
- Or 74min. of audio CD (red-book standard: 44.1kHz/16bit)?

Default Formats

Film:

- **Image:** DPX / TIFF files
- **Audio:** PCM in WAV
- **Metadata:** Mostly sidecar, some MD in image files.

Video:

- **Image:** Default = lossy encoding
- **Audio:** production = PCM, consumer = AAC
- **Metadata:** Often embedded. Sometimes sidecar.

Speaker notes

Film is currently stored as still image sequence (1 frame = 1 file) in a folder, along with the audio as one ore more WAV (PCM) files and optionally metadata sidecar files (XML, etc).

Reels are stored in individual subfolders.

As you can see, I didn't mention which image codec for video, because there is currently still no format option that satisfies the needs of different communities like: archive vs consumer vs production vs broadcast vs cinema.

Question: Where's the difference between *digital* film and *digital* video?

Best practices for A/V Formats

- Capture analog video uncompressed (v210) or lossless (FFV1, J2K) to avoid adding digital generation loss.
- Or as fallback option:
  At the highest quality (data rate) you can store and manage well over time.
- Capture digital tape in its native format without generation loss (MiniDV, DAT, DigiBeta, etc.)
- Store born-digital files "as original" as possible.
- Audio preservation format is uncompressed WAV (PCM) for analog originals.
- For video container formats, consider using MKV or MOV.
  MXF *only* for broadcast.
- Choose formats that can be kept alive (=open & documented)

File formats and preservation implications

Speaker notes

- What do you think "preserves well"?
- What to look out for?
- What to check/ask/know?
- When to acquire that information?

Complexity


WENGER

Speaker notes

Simpler = easier to keep alive, reconstruct or hack.

Good rule: "Minimalistic Standards" * As simple as possible * As complicated as necessary

Be careful with "one size fits all": Sporks are good for camping, but there's a reason why we still have separate tools for the job: spoon, knife and fork.

Considerations:

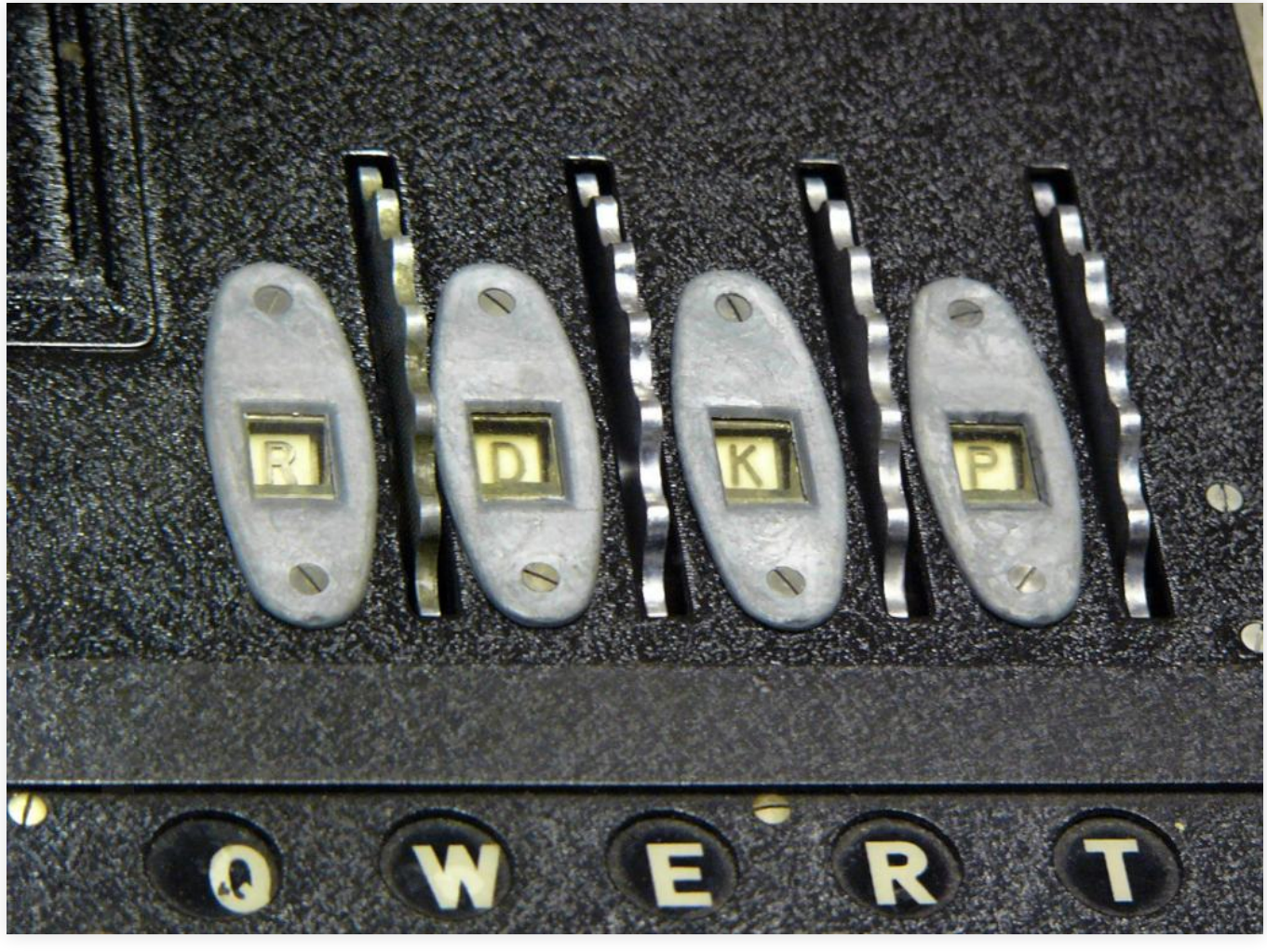
- More features = more complex / chance that only parts of specifications are supported by tool X.
- Can be non-trivial to judge what is "simple" and what is "complex"
- Find the sweet spot for your use case(s).

Format Support

- Popular?
- Documented?
- Well supported?
- Can *you* handle/access it beyond shelf-life?

Speaker notes

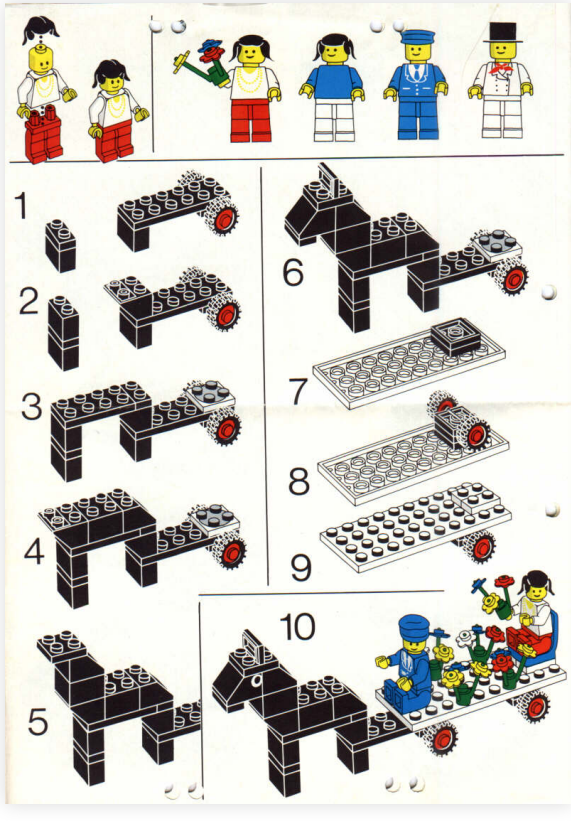
Obsolescence: Open vs Closed



Speaker notes

What will be easier (=more likely) to be understood/accessible now and in the future: Documented language or secret code?

Theory vs Practice

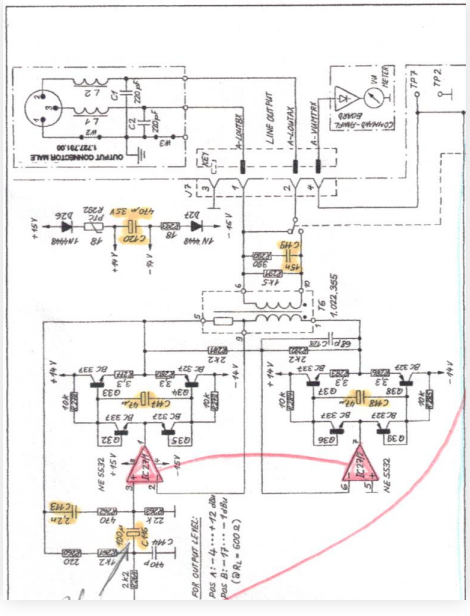


Speaker notes

Implementation trumps paper specs.

If the implementation is open: you can fix/improve if necessary. If it's closed/proprietary then there's nothing you can do about it: Black box. Vendor lock-in.

Schematics



Speaker notes

As an example:

- Schematics
- Building components
- +the right to U.S.S.I them.

= "The Immortal Replayer"

Because it can be kept alive, or rebuilt or adapted to future needs or with future technology (whatever there may be).

Error resilience

Speaker notes

Nice, but don't rely only on it: Make backups!

Popular formats

Speaker notes

Let's take a look at pros/cons of some popular (=significantly present in the wild) and their preservability properties.

Containers

- AVI: Audio Video Interleave
- MOV: Quicktime
- MKV: Matroska Video
- MXF: Material eXchange Format
- WAV / RIFF
- MPG, MTS: MPEG Transport Stream

Video Codecs

- H.264 (lossy, lossless, uncompressed)
- H.265
- MPEG-2 (IMX, XDCAM)
- ProRes
- J2K (lossy, lossless)
- FFV1 (lossless)
- "Uncompressed"

Audio

- AAC
- MP3
- Opus
- PCM
- FLAC

Risks to format longevity

- Data errors
- Obsolescence
- Interoperability issues
- Vendor lock-in

Countermeasures?

Speaker notes

- Data errors: Files are corrupt. These errors may include filenames or filesystem tech-MD.
- Obsolescence: Not supported anymore by accessible tools. This is not God-given, nor irreversible, unless it's a black-box format. Documentation/schematics are an important game changer!
- Interoperability issues: If a format is read and written differently by different applications, it might "morph". This morphed version might work fine with the tools used in a certain environment, but might be completely broken if read/written by another tool that misunderstands the "dialect".
- Vendor lock-in: For long-term preservation, vendor- and technology-neutrality is a must: They will come and go, and with lock-in situations Eternal Migration is hindered or even impossible. Format normalization helps here.

Comments?

Questions?

Links

- Primer on Codecs for Moving Image and Sound Archives
- Hex Editing for Archivists
- Comparing Video Codecs and Containers for Archives