Digital Video:
A guide to good practice

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1. Introduction to digital video

1.1 What is digital video?

Digital video is a popular medium for documenting research projects as a whole, and also for documenting individual elements of a research project such as surveys, laboratory sessions, procedures, and interviews. A rapid advance can be seen both in the ease and availability of video editing applications and in how video can be disseminated, mainly online via sites such as YouTube and Facebook.

This guide aims to provide an overview of digital video files (i.e., video that exists as a digital file either on a recording device or on a computer) but does not cover either the digitization of material or the transfer of material such as digital tapes or DVD-based video to desktop format. As with other data types included in SND's guides, data are best preserved on network-attached storage than on physical media such as DVDs and tapes.

Areas of application

Digital video is often used in the field as a tool to supplement, document and support other data collection techniques. Digital video may also provide an easy way to present a project in which a variety of data collection and analysis techniques have been used, such as 3D modelling or virtual reality (VR). For example, a video fly-through may be a simple way to present the modelled data.

In the past, digital video was usually recorded directly onto DV tape or DVD. Nowadays, devices such as still cameras and mobile phones, or other sources such as 3D models, are often used to produce data. The method by which the video is created may affect its file type, size, and quality. In some cases, a viewable file is usually not created during the filming itself, and further processing on a computer is required to generate such a file. Other devices, such as cameras, may also be very restrictive in terms of the file types they produce.

Reasons for archiving

One reason for preserving a digital video may be that it contains unique original data that are not recorded in any other format, or that the video provides valuable support and documentation to other datasets. Even though no one is likely to want to see all the film created during a project, it is still a good idea to preserve all the material. In marine archaeology, for example, digital video may be used as a tool to assess the condition of a wreck, for example, and monitor damage over time. The films then become a source for historiography. For 3D modelling and interactive 3D environments, a video created, for example, by a simulated flight through them can also provide valuable documentation that cannot be as easily created or stored in other formats. A simulated fly-through is an easy way to disseminate large-scale 3D datasets and can help a user quickly assess the content of the data.

File size and medium

A common problem with digital video in raw, high-quality format is that the data files may be exceptionally large. If edited versions of the video material are created, it is important that informed decisions are made about which versions should be preserved and in which quality format. This should also be weighed against the purpose of the file. For example, is it the only documentation of the project or is the purpose only to support other datasets? In addition, it must be borne in mind that older formats have a short life span and should preferably be transferred to a better storage

medium. A hard disk (internal or external), backed up regularly, is currently the most secure storage medium for the duration of the project. If there are recommendations within the organization for how/where files should be stored, these recommendations should be followed.

2. Things to consider when creating digital video

2.1 General considerations

As mentioned in the previous section, the data/digital video collection medium may determine the format, quality, and final physical size of the video files. When digitising from analogue sources, there are a variety of formats to choose from, as well as a number of considerations that determine the quality and size of the final file. Digitization of material is described in detail in the JISC Digital Media info kit 'High Level Digitisation for Audiovisual Resources'.[1] When creating video files from other datasets (for example a simulated fly-through of a 3D model), there are similar considerations to those described by JISC although the final file format and its quality will be limited by the software used.

Containers and codecs

Like digital images and digital audio files, digital video files contain a range of significant properties (discussed in section 3.2) that affect the quality and size of the video file. Many of these properties are also related to the properties of the container format chosen. However, unlike other file formats, many widely used digital video formats are in fact 'containers'[2] that contain the separate video and audio streams. In simple terms, container formats make life easier for the user by packaging many types of data in one file (audio, image, video, metadata, etc.), instead of having one file for each type of data. These separate streams may in turn also exist in a number of different formats (described in terms of the codec used to encode them) and it is therefore essential for a data creator to be aware of the exact codecs used, and their capabilities and intended use. A codec's job is typically to compress and pack data so that files of a smaller file size can be stored and transferred. There are codecs that preserve the file in its original state, either completely uncompressed or with lossless compression. There are also codecs that use destructive compression. Destructive compression means that some of the information is lost, and the file becomes smaller in size. While it may seem drastic to choose a codec that irreversibly reduces the quality of the video file, the deterioration may not be noticeable to the viewer of the recording. The container format itself may also place restrictions on what can be saved in the format. For example, the MPEG format limits the types of codec that may be used in the container for each stream. However, from a long-term perspective, it is recommended to create and preserve a video file with the highest possible quality in an uncompressed format. Compressed datasets can then be created from this dataset.

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[1] https://www.webarchive.org.uk/wayback/archive/20140701155446/http://www.jiscdigitalmedia.ac.uk/infokit/audiovisual-digitisation Accessed 26 October 2022

[2] A container or wrapper format is a metafile format, the specifications of which describe how different data elements and metadata coexist in a data file. Since the container does not describe how the data or metadata is encoded, there is a risk that an application that identifies and opens container files will not be able to decode the stored information. One reason for this could be that the application lacks the necessary decoding algorithm. By definition, container formats can contain any type of data. Although there are some examples of such more general file formats (for example Microsoft Windows DLL files), most container formats are specialized for specific data requirements.

In general, anyone creating digital video should be aware of:

- Compression, for both video and audio streams. As with many other formats, destructive (lossy) compression results in data loss. Therefore, it is recommended not to use compression when processing the material. If compression must be used, non-destructive compression of the original digital video material should be used, if possible, as this results in a high quality master file on which other files can be based.
- Frame size/pixels per frame describe the physical width and length of a video image and can therefore (as with image resolution) determine the level of detail captured in the file.
- Frame rate (fps) describes the number of frames per second captured/displayed by the file. A higher frame rate produces a smoother video but also a larger file.
- Colour depth (CD). Pixels have only one value and that is their colour. The colour of a pixel is represented by bits and the more bits there are, the greater the nuance in how a colour can be reproduced.
- Bitrate (BR) for both audio and video streams. Bitrate is a value composed of a combination of frame size, number of bits per image and frame rate and indicates the speed of the number of bits sent between different devices, or processed, per unit of time. Many video applications have preset default values that you can use. Apart from these fixed values, some applications also offer the option of a variable bitrate, which allows the video file to adjust the values depending on the complexity of the images. Bitrate is also a value for compressing audio and video streams. The more you lower the bitrate value of a file relative to the original value, the more compressed the file becomes.

An example:
If a video is 30 minutes (1,800 s) long, has 1024x768 pixels per frame (width/height) with a colour depth of 24 bits and a frame rate of 25 frames per second, the video will have the following properties:

Pixels per frame = 1024 x 768 = 786,432

Bits per frame = 786,432 x 24 = 18.87 Mbits

Bitrate (BR) = 18.87 x 25 = 471.86 Mbit/s

Video size (VS) = 471.86 x 1,800 s = 849,346.6 Mbits = 106,168 Mbytes = 106 Gbytes.

Formulae:
BR = W x H x CD x FPS

VS = BR x T = W x H x CD x FPS x T

(The units are: BR in bits/s, W & H in number of pixels, CD in bits, VS in bits, T in seconds)

3. Archiving digital video

3.1 Deciding what should be preserved

Deciding what to preserve depends on how the digital video was created. As mentioned earlier, many of the tools you can use to create videos have limitations in terms of quality and the file types that can be created. It is therefore particularly important to evaluate the limitations of the intended recording tool and the requirements of the project. The quality of the digital video should be such that it is suitable for archiving, for example by choosing the right file format. This applies to the original file, but also to compressed versions created from the original. However, storing completely uncompressed video files is not always ideal,[3] and should be considered on a project-by-project basis. This makes it particularly important to choose an appropriate format if and when changing file formats, as it is not possible to revert or improve data if a lower quality format has been chosen. Below are a number of factors to consider when converting data from one format to another.

3.2 Deciding how it should be preserved

Significant properties

The properties of a video file that should be preserved in their original form when a video file is stored or archived can be summarized as follows:

- the length and size of the file (for example 6 min 23 s/185 MB)
- the number of frames per second (for example 25 for PAL or 30 for NTSC)
- the frame size (for example 720 x 576 pixels)
- the image bitrate (kbps)
- the audio bitrate (kbps)
- the audio frequency (kHz)
- the number of audio channels used (for example stereo)
- associated metadata and documentation.

Before converting a video file, you should check it against the available documentation to ensure that the film has the specified length (minutes and seconds) and that its most significant properties are correctly documented. This is to make sure that the file is complete and that it does not suffer any unplanned degradation during the conversion.

The process of converting digital video, i.e., migrating data from one file format to another, is described on the JISC Digital Media website.[4]

[3] Uncompressed files are larger than compressed files, which may cause problems if storage space is limited. In addition, uncompressed files may sometimes contain junk sequences that simply take up space without containing any information. At the same time, the choice to save video files in compressed formats should be carefully considered, as destructive compression will lead to irreversible loss of information.

[4] http://www.webarchive.org.uk/wayback/archive/20160101151817/http://www.jiscdigitalmedia.ac.uk/guide/transcoding-digital-video Accessed 26 October 2022

3.3 Metadata and documentation

As with other types of data, the digital video metadata provide vital information about how the video was created. Apart from basic project-level metadata, metadata associated with the digital video should be stored so that their structure can be understood.

Element	Description
Software, version, and its platform (type of recording tool)	The software (or hardware if the file is taken directly from the recording device) used to create the video.
Video codec	Name and version of the video codec.
Dimensions	The dimensions of the video, i.e., the height and width (in pixels, for example 1024 x 576).
Frame rate	Number of frames per second (fps).
Bitrate	The video bitrate (in bits per second).
Audio codec	Name and version of the audio codec.
Sampling rate	Specifies the average number of samples[5] retrieved per second.
Audio bitrate	The bitrate of the audio (in bits per second).
Audio channels	Channels used, for example stereo.
Length	Length of the video (hours, minutes, seconds).
File size	Size of the file in MB.

[5] https://www.digitizationguidelines.gov/term.php?term=samplingrateaudio Accessed 22 February 2023.

4 Video format

The tables below describe some common codec and container formats used for digital video files. Some of these formats may appear obsolete, but they are described here because it may be necessary to handle older file formats. More detailed comparisons of the functions of these formats may be found in Wikipedia's *Comparison of video container formats*[6] and in Wikipedia's *Comparison of video codecs.*[7]

Audio Video Interleave	
File format/extension	AVI/ .avi
Format	A proprietary,[8] binary[9] container format for both audio and video developed by Microsoft.
Container/codec	Container
Description	A common container format that supports a number of codecs but has some limitations owing to old specifications: it cannot reliably contain certain types of variable bit rate (VBR) data[10] (for example MP3 with sampling rates below 32 kHz), and it does not have a standardized way of encoding information about image proportions, so playback software does not automatically detect the proportions.[11] The format has its origin in the Resource Interchange File Format (RIFF). In accordance with the RIFF format, the Avi container consists of three parts: the first, the header labelled *hdrl*, contains metadata about the file (width, height, fps, etc.). The second, labelled *movi*, contains a number of packets of video and audio data in almost any type of compression, and a third optional part, labelled idx1, which if used indexes any offsets (amplitude and time/phase shifts of audio and video) that exist in the various parts of the AVI file.[12, 13]
Recommendations	Works for dissemination, but not suitable for archiving.

[6] http://en.wikipedia.org/wiki/Comparison_of_container_formats Accessed 26 October 2022
[7] http://en.wikipedia.org/wiki/Comparison_of_video_codecs Accessed 26 October 2022
[8] **Proprietary** software is software that has restrictions (usually set by the owner) on using, modifying, or copying it.
[9] **Binary file**, a file containing data in a format intended to be read by specific computer programs, with a substantial portion of the information encoded as other than text. Binary files generally cannot be interpreted without knowledge of the file format, except possibly to some extent.
[10] https://en.wikipedia.org/wiki/Variable_bitrate Accessed 26 October 2022
[11] http://www.digitalpreservation.gov/formats/fdd/fdd000059.shtml Accessed 26 October 2022
[12] https://en.wikipedia.org/wiki/Audio_Video_Interleave Accessed 26 October 2022
[13] http://www.digitalpreservation.gov/formats/fdd/fdd000059.shtml Accessed 26 October 2022

DivX Media Format[14]	
File format/extension	DivX ;-) 3.11 Alpha up to DivX 5.xx/ (.divx, .avi)
Format	Proprietary video codec.
Container/codec	Codec
Description	The DivX ;-) 3.11 codec and later 3.xx versions are based on a hacked variant of the Microsoft MPEG-4 Version 3 video codec. The DivX format is another application of MPEG-4 and is often used to distribute films online. The format from version 4 onwards (also known as OpenDivX) was developed from scratch but is compatible with Microsoft MPEG-4 Version 3.[15] The DivX codec is free to download but requires a license to encode.
Recommendations	Works for dissemination, but not suitable for archiving.
File format/extension	DivX 6 / (.divx, .avi)
Format	With DivX 6, the format was expanded from being just a codec to also function as a container. The format is used for the MPEG-4 Part 2 codec; a codec developed by MPEG.[16]
Container/codec	Codec and container format
Description	The file format is a development of the AVI format. Therefore, it may contain several video, audio, and subtitle files, among others.[17]
Recommendations	Works for dissemination, but not suitable for archiving.

Flash Video	
File format/extension	FLV, F4V/ .flv, .f4v
Format	A proprietary container format that uses Adobe Flash Player to display digital videos online and on other platforms (for example YouTube).

[14] http://www.digitalpreservation.gov/formats/fdd/fdd000069.shtml Accessed 26 October 2022
[15] http://www.digitalpreservation.gov/formats/fdd/fdd000069.shtml Accessed 26 October 2022
[16] https://en.wikipedia.org/wiki/MPEG-4_Part_2 Accessed 26 October 2022
[17] https://en.wikipedia.org/wiki/DivX Accessed 28 October 2022

Container/codec	Container
Description	There are two different file formats linked to Flash Video: .flv and .f4v.[18] The .flv format, developed by Macromedia and later Adobe, normally supports material compressed with codecs defined according to the Sorenson Spark[19] or VP6[20] compression formats. .flv works for Adobe Flash Player 6 and later. .f4v was developed by Adobe, originated in MPEG-4 Part 12 and was included with Flash Player 9.3. The format also supports material compressed using the compression standards H.264 for video (MPEG-4 Part 10, Advanced Video Coding)[21] and HE-AAC for audio (High-Efficiency Advanced Audio Coding).[22]
Recommendations	Works for dissemination, but not suitable for archiving.

Matroska Multimedia Container	
File format/extension	Matroska/ .mka (audio), .mkv (video), .mk3d (3D video)
Format	An open standard container format, free to use, but with some parts licensed under GNU L-GPL.[23, 24]
Container/codec	Container
Description	Matroska is a flexible, cross-platform container format for multimedia. The format may contain any number of video, audio, image, or subtitle files in a single file[25] and is intended to become the open source alternative to existing proprietary containers such as AVI, ASF, MOV, RM, MP4, MPG ES.[26]
Recommendations	Suitable for dissemination and archiving, depending on the codec used.

[18] https://en.wikipedia.org/wiki/Flash_Video Accessed 3 November 2022
[19] https://en.wikipedia.org/wiki/Sorenson_Media#Encoding_Technologies Accessed 3 November 2022
[20] https://en.wikipedia.org/wiki/VP6 Accessed 3 November 2022
[21] https://en.wikipedia.org/wiki/H.264/MPEG-4_AVC Accessed 3 November 2022
[22] https://en.wikipedia.org/wiki/High-Efficiency_Advanced_Audio_Coding Accessed 3 November 2022
[23] https://www.gnu.org/licenses/lgpl.html Accessed 3 November 2022
[24] http://www.matroska.org/ Accessed 3 November 2022
[25] http://www.digitalpreservation.gov/formats/fdd/fdd000342.shtml Accessed 3 November 2022
[26] https://www.matroska.org/what_is_matroska.html Accessed 3 November 2022

Motion JPEG 2000	
File format/extension	JP2/ .mj2, .mjp2
Format	An ISO/IEC 15444-3 standard, using JPG2000 encoding.[27]
Container/codec	Container
Description	Can store both destructive *(*lossy) and non-destructive *(*lossless) video. The Motion JPEG 2000 format stores video as a series of individual images, which is why it attracted early interest in digital preservation circles, particularly for film digitization. It uses a technique in which each video frame is encoded separately (intra frame[28]) as opposed to techniques (for example MPEG) that, if information is the same for adjacent frames, share that information *(*inter frame[29]). The advantage of encoding the frames separately is that the risk of any miscoding of the material spreading within the file is significantly reduced, the format is more scalable, and it is also easier to view individual frames, but at the cost of storage space and greater bandwidth.[30] The result depends on the degree and type of compression and the codec used.[31]
Recommendations	Works well for the dissemination and archiving of data.

Moving Picture Experts Group (MPEG)	
File format/extension	MPEG-1/ (.mpg, .mpeg)
Format	An open standard, binary format for video and audio. Destructive (lossy) compression, but without degrading the quality significantly.
Container/codec	Codec
Description	An international ISO/IEC standard (11172)[32] developed by the Moving Picture Experts Group (MPEG) for Video CD (VCD and SVCD) and less commonly DVD-Video. Provides reasonable quality for audio/video playback comparable to

[27] http://www.digitalpreservation.gov/formats/fdd/fdd000127.shtml Accessed 3 November 2022
[28] https://en.wikipedia.org/wiki/Intra-frame Accessed 3 November 2022
[29] https://en.wikipedia.org/wiki/Inter_frame Accessed 3 November 2022
[30] https://en.wikipedia.org/wiki/Motion_JPEG_2000 Accessed 3 November 2022
[31] https://www.loc.gov/preservation/digital/formats/fdd/fdd000127.shtml Accessed 3 November 2022
[32] https://www.iso.org/standard/25371.html Accessed 3 November 2022

	VHS tapes. Many tools, including open source tools, are available to work with this format. Works well for video at rates up to 1.5 Mbps.[33] MPEG-1 Audio Layer III is the same as MP3 but is a sub-format of MPEG-1. *MP3* is a destructive codec that also allows metadata (ID3) to be embedded in the file. The format is perhaps the most common standard for music files online. Most media players support MP3. The MP3 format was further developed into MPEG-2.
Recommendations	Works for dissemination and archiving.[34] If the file was originally created in a better quality format, it should be saved in that format.
File format/extension	MPEG-2/ (.mpg, .mpeg)
Format	Open standard
Container/codec	Codec
Description	As for MPEG-1, an ISO/IEC standard (13818),[35] but for DVD and digital TV.[36] It contains a number of different profiles (Simple Profile,[37] Main Profile,[38] and 4:2:2 profile,[39] the last of which is used for digital TV), all of which contain different standard specifications for elements such as screen size and data rate. MPEG-2 video is not optimized for low bit rates (i.e., less than 1 Mbps) but provides superior quality compared to MPEG-1 at rates above 3 Mbps.
Recommendations	Recommended for archiving.
File format/extension	MPEG-4/ (.mp4)
Format	An ISO standardized format.
Container/codec	Container
Description	The newest of the MPEG ISO/IEC standards (14496[40]), it is adapted for the web (streaming media), voice (videophone) and TV broadcasting, all of which

[33] http://www.digitalpreservation.gov/formats/fdd/fdd000035.shtml Accessed 3 November 2022
[34] However, the Library of Congress' Packard Campus for Audio-Visual Conservation recommends MPEG-2, Main Profile (lossless JPEG 2000 wrapped in MXF operational pattern 1a) for archiving.
[35] https://www.iso.org/standard/44169.html Accessed 3 November 2022
[36] http://www.digitalpreservation.gov/formats/fdd/fdd000335.shtml Accessed 3 November 2022
[37] http://www.digitalpreservation.gov/formats/fdd/fdd000033.shtml Accessed 3 November 2022
[38] http://www.digitalpreservation.gov/formats/fdd/fdd000032.shtml Accessed 3 November 2022
[39] http://www.digitalpreservation.gov/formats/fdd/fdd000034.shtml Accessed 3 November 2022
[40] https://www.iso.org/standard/75400.html Accessed 3 November 2022

	benefit from compressing the AV stream. Based partly on Apple's QuickTime .mov format, it has MPEG-4 at its core for audio and video, but also supports 3D objects, text, *sprites,* and other types of media to allow interactive elements to be included. As for MPEG-2, MPEG-4 contains two main versions and a large number of profiles optimized for different purposes.[41] The format is being used more and is well described at NDIIPP. MPEG-4 part 10 (ISO/IEC 14496-10:2003[42]), technically equivalent to the International Telecommunication Union standard ITU-T H.264: Advanced Video Coding.[43] The codec is one of the video encoding formats for Blu-Ray and for HDTV broadcasting in Europe. MPEG-4 part 14 (ISO/IEC 14496-14:2003[44]) is a commonly used container format that supports a number of different audio codecs (for example AAC, MP3) and embedded metadata (including XMP). Most video playback applications support MP4. MP4 files may contain a number of audio, video, and subtitle streams.
Recommendations	MPEG-4 is suitable for preservation and dissemination, but higher quality MPEG formats should be used where possible.

Material eXchange Format[45]	
File format/extension	MXF/ .mxf
Format	The Material eXchange Format (MXF) is an open container format for video and audio data with the option of a large volume of metadata.
Container/codec	Container
Description	An open standard developed by the Society of Motion Picture and Television Engineers (SMPTE[46]). The format follows a number of the organization's standards.[47] MXF has full support for metadata and timecodes.[48] Designed to

[41] http://www.digitalpreservation.gov/formats/fdd/fdd000155.shtml Accessed 3 November 2022
[42] https://www.iso.org/standard/37729.html Accessed 3 November 2022
[43] http://www.itu.int/ITU-T/recommendations/rec.aspx?rec=12904&lang=en Accessed 3 November 2022
[44] https://www.iso.org/standard/38538.html Accessed 3 November 2022
[45] https://www.loc.gov/preservation/digital/formats/fdd/fdd000013.shtml Accessed 3 November 2022
[46] https://www.smpte.org/ Accessed 3 November 2022
[47] https://en.wikipedia.org/wiki/Society_of_Motion_Picture_and_Television_Engineers Accessed 3 November 2022
[48] https://en.wikipedia.org/wiki/SMPTE_timecode Accessed 3 November 2022

	be cross-platform and a stable standard for professional use in the film and audio industry.[49]
Recommendations	Works for dissemination. Suitable for archiving, especially if the specification AS-07[50] was used.

QuickTime File Format	
File format/extension	QTFF/ .mov
Format	A proprietary container format developed by Apple.
Container/codec	Container
Description	A container format for video, audio, and other streamed material such as images, animations (not created as video), VR, etc. As mentioned above, the format is the basis for MPEG-4. Although the QuickTime format has equivalent and, in some cases, better functionality, it is better to use the open MPEG-4 format where possible.[51]
Recommendations	Works for dissemination, but not suitable for archiving.

Xvid	
File format/extension	Xvid/ .avi, .xvid
Format	A GNU GPL licensed codec based on MPEG-4 and a further development of OpenDivX.[52]
Container/codec	Codec
Description	XviD, like DivX, is based on the MPEG-4 Part 2 Advanced Simple Profile (ASP).[53] The main difference between Xvid and DivX is that the former is an open

[49] https://en.wikipedia.org/wiki/Material_Exchange_Format Accessed 3 November 2022
[50] https://www.amwa.tv/specifications Accessed 3 November 2022
[51] http://www.digitalpreservation.gov/formats/fdd/fdd000052.shtml Accessed 3 November 2022
[52] https://www.xvid.com/ Accessed 3 November 2022
[53] https://en.wikipedia.org/wiki/Xvid Accessed 3 November 2022

	format and works for all platform types and operating systems for which source code can be created.
Recommendations	Works well for the dissemination of data but is not suitable for archiving.

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