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2

Title: The Digital Video Archive
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The Digital Video Archive

0. Introduction

Video is a technology developed in the second half of the 20th Century with the aim of making the electronic representation of moving images possible. In the first four decades of its existence, video signals were recorded in analogue form (continuous) onto a physical medium such as magnetic tape. At the turn of the century, digital video, in which video signals are transmitted through impulses or bits (discontinuous) and are encoded according to a binary numeric system, started to become widespread (although its development took place a few years earlier). Today, analogue video is an obsolete technology and, in all areas, has been replaced by digital video, from industrial production and commercial distribution to home video.

Magnetic videotapes are fragile materials, highly vulnerable to physical degradation. Furthermore, playing the tapes requires a video recorder, which nowadays, is difficult to find or to maintain in good working condition. For this reason, archives are working to digitalise magnetic videotapes in order to preserve their content. Thus, in archives, there are digital video documents that have been produced through the digitalisation of magnetic tapes side-by-side with those that were created in digital format.

If analogue video is defined by the physical characteristics of the medium (the width of the tape, the composition of magnetic particles, etc.) digital video is defined by a series of numeric parameters such as resolution, sampling rate, the quantification and bit depth, amongst others. The numerical differences of the various parameters, and the way they structure the data so that it is readable by a machine, is what gives rise to the various formats.

1. The main parameters that characterise a digital video file

Frames per second
Just like analogue video, digital video gives the impression of a moving image by relaying a series of static images at high speed. In analogue video, the number of images (frames) per second was 25 for the PAL system and 30 for the NTSC system. The digital video standard keeps the same frames per second ratio.

Resolution
Each digital image or frame is formed by a series of points of different intensities of brightness and colour. These points or pixels form a grid of vertical and horizontal lines. Resolution is the number of pixels the image is divided into or, in other words, the number of rows of pixels (X) by the number of columns (Y). There are different standards of resolution according to the characteristics of the format and the display medium: 720x576, 1280x720, 1920x1080, etc.

Aspect ratio
This refers to the ratio of the rectangle that forms the image. In the analogue video era, the ratio was always 4:3. When digitalising analogue videotapes, this ratio must be maintained so as not to distort the original image. In the last decade of the 20th

century, a 16:9 ratio, that it to say a more panoramic ratio, became prevalent. The 16:9 ratio predominates in digitally created video.

Bit Depth or Quantification

Each pixel is given a value, which determines the brightness and colour information. The greater number of bits assigned to quantify this value, the greater the number of tones that may be rendered. This progression is exponential. If we take as an example a grey-scale between the black and the white, an 8-bit encoding can represent 256 shades (2^8), while a 10-bit encoding can represent 1,024 shades (2^{10}).

Bit rate

This is the number of bits that must be transferred per second for a digital video file to play correctly. A quality video encoded in high resolution and with low compression, will need a high rate of bit transfer in order for it to be played, and will therefore require powerful processors and a considerable bandwidth.

Sampling rate

The sampling rate is the number of samples taken per second of the analogue signal in order to convert it into a digital signal. The sampling rate is measured in hertz. The ITU-R BT 601 standard, the first standard for digital television, established a sampling rate of 13.5 MHz for the luminance signal and two of 6.75 MHz for the chrominance (colour difference) for reproduction in the 4:3 screen format. This standard has been superseded by other standards for the 16:9 screen ratio and for higher resolutions requiring a higher sampling frequency.

Subsampling

In the analogue video signal, brightness and colour are transmitted separately in three channels (YUV signal): a brightness or luminance signal (Y) and two colour chrominance signals (UV). This is the same for digital video and is represented as YCbCr.. If the total numbers of samples for the three signals are represented as 4:4:4, some forms of subsampling are represented as 4:2:2, 4:2:0 or 4:1:1, i.e. a lower number of chrominance samples are taken for each luminance sample. It is possible to reduce the number of colour samples to maintain the brightness information without perceiving changes to the image because the human eye is less sensitive to colour than it is to variations in light intensity.

Scanning

In video technology the image is scanned onto the screen in horizontal lines, which follow each other at high speed. Due to the technological limitations of the first televisions, each image wasn’t formed in a single scan but rather, first the even numbered lines were scanned, then the odd (or vice versa). This system is known as interlacing. Digital video in standard definition (SD) for a 4:3 screen ratio keeps the interlaced system. The other system is progressive scanning whereby the whole frame is constructed in a single scan and is used mainly in digital high definition (HD) video.

Digital video compression

Digital video files contain lots of information that must be processed, transferred, and stored. This has led to the need to develop systems able to reduce the number of bits in a video sequence. A compressed video format can achieve a reduction in the number of bits contained in an uncompressed video file by tens or even hundreds of times.

A distinction is usually made between formats that employ lossless compression systems (lossless) and those that present losses of information (lossy). Obviously, the former is preferable but the technological resources of archives and their storage capacities do not always allow this.

2. Video formats

A format is a particular way of codifying and structuring digital information in order to store it in a file. There are formats that can contain different information streams such as video, audio, graphic images or metadata. They are called container formats (wrappers) and are especially important for digital video storage. Container formats should be differentiated from codecs, which constitute the set of algorithms used in the encoding of digital video and audio. The same container format can support different codecs.

Some of the most common video codecs and container formats are:

Container formats	
Advanced Authoring Format (AAF)	This is a container format for professional use which stores audio and video information and, along with this, encapsulates the metadata needed for its reproduction. It is a format optimised for sharing content across different platforms and applications.
Advanced System Format (.asf)	This is a container format developed by Microsoft that can contain different data streams including audio and video. It was designed primarily for streaming, i.e. to deliver video over the Internet. It is associated with the video and audio formats Windows Media Video and Windows Media Audio.
Audio Video Interleave (.avi)	It is an audio and video container format developed by Microsoft and is considered to be one of the de-facto standards for video storage. The audio and video stream can be encoded using different video codecs such as MJPEG or MPEG-2 or audio codecs such as AC3 or MP3.
Quicktime (.mov, .qt)	This is a video format developed by Apple. It is cross-platform, i.e. it can run on different operating systems and supports a good number of codecs. It is capable of encapsulating various audio, video, and multimedia content streams. It is widely used as the format for professional video editing.
Motion JPEG 2000 (MJ2 o MJP2)	Based on the JPEG 2000 set of standards for digital image coding, Motion JPEG 2000 is used for the coding of moving image sequences and digital audio. An MJ2 video sequence can be formed by frames encoded separately using JPEG 2000. Motion JPEG 2000 has been established as the standard for the encoding of digital cinema.
MPEG-4	As the container format of the MPEG (Motion Picture Experts Group), MPEG-4 defines a series of tools for coding audiovisual and multimedia objects. Its applications include interactive television, multimedia mobile telephony and *internet video streaming*. In its part 10, it defines the AVC (Audio Video Coding) compression codec equivalent to the H.264 standard.

Material Exchange Format (MXF)	This is a subtype of AAF for digital video. It has been developed by the SMPTE (Society of Motion Picture and Television Engineers) and supports a large number of different data streams encoded with various codecs. It has established itself as a standard for the archival storage of digital video.
Flash Video (.flv)	It is a container format developed by Macromedia and acquired by the company Adobe Systems (2005), used mainly to deliver video via the internet. It is associated with the Adobe Flash multimedia player and is commonly used with the Sorenson Spark, VP6 and, more recently, the H.264 codecs.
Ogg (,ogg)	This is a container format that encapsulates audio, video and other data streams such as text or metadata. Because it is open source, several codecs developed for Ogg, like Theora (video) and Vorbis (audio) have been incorporated into a large number of media players.
Matroska (.mkv)	This is an open-source and cross-platform container format which is associated with free software applications. It claims to be an audiovisual container format for universal use. It supports different video codecs such as MPEG2, MPEG4-ASP (DivX6 or XviD), H.264 (X 264) and Theora, and audio such as MP3, AC3 or DTS.

Video codecs	
DV (Digital Video)	The DV format appeared in 1995 with the purpose of applying digital technology to the recording of video onto magnetic tapes in cameras, but later it also began to be used for other storage devices such as hard drives. The DVCAM and DVCPRO formats (and their high definition versions), used for recording video in a professional environment, or MiniDV, for the domestic environment, belong to the same family.
MPEG-2	This can be both a container format and a video codec. The MPEG-2 standard includes standards for multiplexing of video, audio and other data streams. It was initially developed to serve as a basis for the digital television standard and was later adopted as the standard for the distribution of DVD-Video.
Divx (.divx)	It originated as a proprietary video format, based on the MPEG-4 standard, for the renting of films. In 2000, the Dvix Inc. Company was founded and, in the following years, it worked on an open source version, OpenDivx, which would result in one of the most popular codecs for the distribution of audiovisual content over the Internet, Xvid (based on MPEG-4 ASP).

Motion JPEG (MJPEG)	This is a video encoding format in which each frame is compressed using JPEG. It doesn't offer a high rate of compression but encodes each frame separately. It has been used for some time in non-linear video editing systems. MJPEG formats are often found contained in AVI or Quicktime files.
Windows Media Video (.wmv)	This is a proprietary video format from the Microsoft Company mainly used for video streaming. The latest versions of WMV allow the encoding of high definition video. This format is associated with Windows Media Audio and with the .asf container format.
FFV1 (FF video codec 1)	This is a lossless intra-frame codec, i.e., which encodes each frame separately. It is part of the open source *Ffmpeg* project.. It is a codec which meets the needs of long term storage which is why it should be taken into account by archives. It may be associated with containers such as AVI and Matroska.

Digital audio formats

Besides video codecs, the audio codecs used in digital video should be taken into account. The most common digital audio formats are **WAV** or WAVE (Wave Audio Format), **AIFF** (Audio Interchange File Format), **LPCM** (Linear pulse-code modulation), **AAC** (Advanced Audio Coding), **Dolby Digital (AC-3),** MPEG-1 Layer III, better known as **MP3**, and **Windows Media Audio**, among others.

Not all video and digital audio formats are suitable for conservation in a long-term storage archive. In order to be suitable, they should meet two main requirements: they should not present any loss of data and they should be accessible in the future.

3. Metadata

Traditionally, archives and documentation centres have developed norms and standards for the cataloguing of documents, and also for audiovisual documents. Institutions such as film or sound libraries catalogue their documents according to the standards published by professional associations such as the FIAF (FIAF Cataloguing Rules), the IASA (IASA Cataloguing Rules) or the AMIA (AMIA Compendium of Moving Image Cataloguing Practice).

These standardising cataloguing frameworks require great effort in their creation and maintenance, and are not very adaptable to technological changes or to new contexts of document production and distribution. Therefore, other forms of characterising the documents have been developed that, without being substantially different, are used to perform particular functions or to meet the needs of a particular user group. These are called metadata schemes.

Metadata is data that is added to the document to describe its physical and formal attributes, its location, the rights that affect it or its connection to other documents. This metadata is added to the document in the form of languages that have been specifically designed for this purpose, such as XML or RDF.

Many archives that hold audiovisual documentation employ metadata models created by the organisation itself. However, regardless which metadata model is used, what is important from the point of view of long term preservation, as well as for the distribution and exchange of content, is the possibility that each of the elements can be designated by a universal identifier that is intelligible by different platforms and applications.

There are various metadata standards that fulfil different functions such as the description of the collection of an archive, the conservation of digital repositories, the sharing of content between broadcast companies, etc. (METS, EAD, PREMIS, Dublin Core, etc.). Some of these are used expressly for the description of audiovisual and digital video documents:

MPEG-7: This is an ISO/IEC metadata standard developed by the Moving Experts Group (MPEG) which provides a framework for the representation and description of audiovisual content in multimedia environments.

MPEG-21: This is also a standard from the MPEG ISO/IEC group and has been developed with the aim of providing a standardised framework of metadata that provides secure access to the audiovisual information.

EBU P/Meta: It is a metadata schema developed by the EBU/UER (European Broadcasting Union) intended for the exchange of audiovisual content between broadcast television and radio companies..

PBCore: This was developed in 2005 by the Corporation for Public Broadcasting with the aim of serving the broadcast media community in the United States.

EBUCore: It provides a structure of technical and descriptive metadata for use in a wide range of broadcast applications.

AudioMD and VideoMD: These are two metadata schemas created by the Library of Congress for its digital library projects and they include the technical information required for the description of audio and video files respectively.

4. Storage

The choice of a storage system should be made according to the size of the archive and the functions it must fulfil. The choice of a massive storage system able to contain all the documents in the archive in one device, or as few as possible, is recommended. A mass storage system facilitates the centralised management of a large number of digital objects through an electronic control system.

The mass storage systems that are most used in audiovisual archives are based on hard disks and magnetic data tapes. A mass storage system can be composed of different devices connected to each other, some of which are used to store data for immediate access (*online*) and others to store data accessed less frequently (*offline*). The architecture of a storage system depends on certain factors such as the size of the collection or the data access requirements.

Hard Disks

The increase in the capacity of hard disks (HD) and the reduction of their cost has made this technology one of the most common digital storage options. Estimates of the useful life of hard drives do not go beyond five years so it will be necessary to plan for the transfer of documentation to other media. Furthermore, creating copies onto different disks becomes essential in ensuring the security of the data.

Magnetic data tapes
Magnetic data tape is another storage device commonly used in digital video archives. Currently there are tapes capable of storing up to 2.5 TB uncompressed (LTO-6). The tape medium offers slower access speeds than hard drives, however, it also offers a high density of data which translates into a lower storage cost per bit. Currently the most typical form of data tape is a reel housed in a cartridge.

Tape systems are usually associated with an automated system of data recovery known as a tape library. These systems have the advantage of being scalable, i.e. the number of cartridges can be increased, thus increasing storage capacity.

5. Preservation and access

Content management
Archives have always created descriptive tools to identify and locate documents, as well as to arrange and classify them according to their origin, their functions, their type or their thematic content. The first step in applying information technology to the development of the descriptive tools of archives was the creation of databases which allowed this meta-information to be organised, at first in a way similar to traditional catalogues, and later with the creation of new associations between the data which offered more efficient information management.

Today databases continue to be used with the information structured in a way that allows for the identification and location of documents in an archive, but new software has also been developed which is able to efficiently manage large numbers of digital objects associated with documents of different natures such as images, text or multimedia documents. These are known as Document Management Systems (DMS). The advantage of these systems is that they allow the management of information that is not structured in the same way as information contained within a database, either because it originates from different sources (cameras, internet links, editing sections etc.), or because it changes constantly with the interaction of different users.

Specialised systems for the management of audiovisual and multimedia documents are known as MAM (Media Asset Management) systems. These systems may have different features such as:

- Automatic inclusion in the system of content from different sources
- Movement of files between different devices
- User interfaces for the description and addition of metadata
- The classification of documents through taxonomies and the organisation of these in directories or folders
- Access for displaying documents
- Control of users and access privileges
- Search and information retrieval tools
- Broadcasting in web environments

Digital preservation
For digital video, the risk of loss due to physical degradation of materials is much lower than for the analogue video, since the data can be copied indefinitely to other storage devices without causing any loss of information. However, preserving the string of bits is not the same thing as preserving the audiovisual content since, for the latter, it also requires the technology that allows the data to be interpreted i.e. a computer and

software able to convert this string of bits into images and sound. Digital preservation also includes the preservation of the context information, i.e. all the information related to the circumstances of the document's creation: its authorship, origin, date of creation, etc.

Backup copies
Key to ensuring that data is preserved, even if the physical medium fails or is accidentally destroyed, is the creation of backup copies onto other media.. It is recommended that the data of the original digital object and the backup copies are located on independent media, physically isolated from each other, to ensure the survival of at least one copy in case of disaster. Also, it might be advisable to use different digital storage technologies in order to take advantage of the different characteristics of the media in terms of access, robustness and economic cost, amongst others.

Conservation of technology
This is based on the preservation of the digital document together with the technology that allows its reproduction. This method has the advantage of maintaining all the original characteristics of the document, both the information we perceive as well as that relating to the context of its creation. However, this involves a huge effort in terms of the maintenance of obsolete hardware and software.

Migration
This method involves the transformation of the digital object but not the information it contains, so that the documents can continue to be usable on a new technology when the previous one has become obsolete. Currently, this is the most commonly used strategy although it can also involve a considerable effort in terms of time and resources.

Transfer to new media
This is the transfer of digital objects to other newer or more secure media. In this case the digital object maintains its original characteristics.

Emulation
This is based on the recreation of the technological environment in which the original document was created so that it can be reproduced without having to make any changes to its structure. Though in theory it is the most rational strategy, in practice it is very difficult to preserve all the knowledge associated with the technology of a particular era. However, this can be much improved by using self-documenting formats which carry readable information within themselves which facilitates their reproduction in whatever era.

6. Conclusions

The existence of multiple digital video formats requires archivists to know not only their different characteristics but also to anticipate their degree of obsolescence and to plan for the migration of files to new formats.

Digital video is stored on a physical medium that, unlike analogue video, can be replaced without causing any substantial changes to the content. Mass storage systems are preferred by archives for preserving digital video as they offer various advantages, the main one being that tasks which affect many documents can be automated.

Besides the audiovisual information, a digital video file contains other data that provides information about the technical characteristics of the document: its content, intellectual property rights, the origin, changes or alterations that it has undergone throughout its life cycle, etc. This is what is known as metadata. Metadata can be created automatically at the same time as the file is generated, or can be added later manually; it can be encapsulated in the same bundle and accompany the file or can form part of an external database and be associated with the file logically through links. Metadata management is essential to ensure the preservation and access to a digital video file.

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