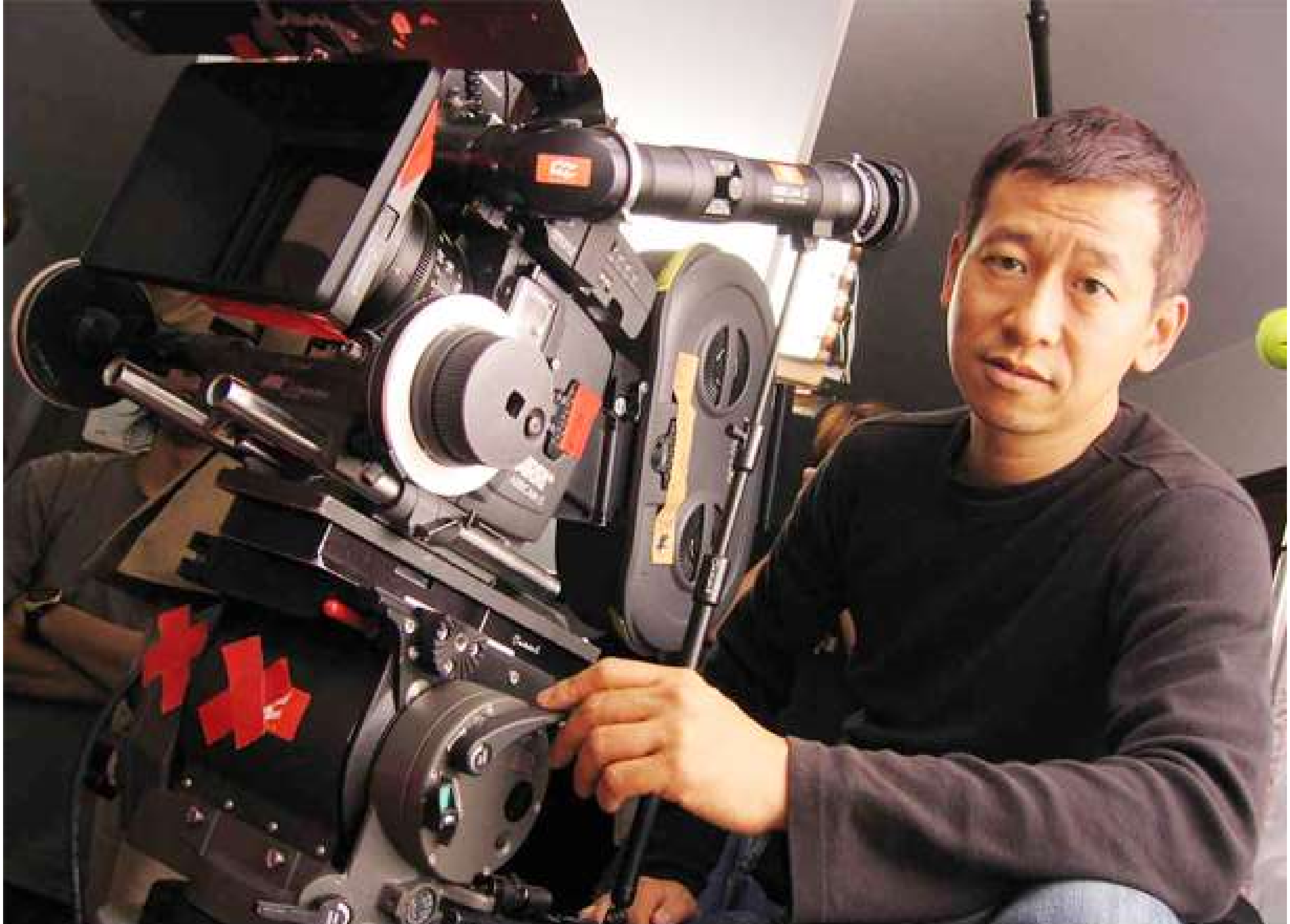

Handbook of Film and Video Technology

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Digital Cinematography

Digital Cinematography is the process of capturing motion pictures as digital images, rather than on film. Digital capture may occur on tape, hard disks, flash memory, or other media which can record digital data. As digital technology has improved, this practice has become increasingly common. Many mainstream Hollywood movies now are shot partly or fully digitally.

Many vendors have brought products to market, including traditional film camera vendors like Arri and Panavision, as well as new vendors like RED and Silicon Imaging, and companies which have traditionally focused on consumer and broadcast video equipment, like Sony and Panasonic.

Digital cinematography's acceptance was cemented 2009 when *Slumdog Millionaire* became the first movie shot mainly in digital to be awarded the Academy Award for Best Cinematography and the highest grossing movie in the history of cinema, *Avatar*, not only was shot on digital cameras as well, but also made the main revenues at the box office no longer by film, but digital projection. In 2010 the Academy Award for Best Cinematography again was won by a movie shot digital, and the Academy Award for the Best Foreign Language Film, El secreto de sus ojos, as well was won by a movie shot digitally.

History

Beginning in the late 1980s, Sony began marketing the concept of "electronic cinematography," utilizing its analog HDTV cameras. The effort met with very little success. In 1998, with the introduction of HDCAM recorders and 1920 × 1080 pixel digital video cameras based on CCD technology, the idea, now re-branded as "digital cinematography," began to gain traction in the market.

In 1994 Sony Executives approached "Party of Five" (FOX) producer, Ken Topolsky and director of photography Roy H. Wagner ASC, in an effort to photograph side by side tests with Sony's prototype High Def camera and 35mm film. This resulted in one of the first network broadcast television series, FOX Pilot PASADENA (2001), directed by Diane Keaton, photographed by Wagner. The results were so successful, shown to directors and Industry decision makers at the Directors Guild of America and Society of

Motion Picture and Television Engineers (SMPTE) meetings, that many were encouraged by the film like images. Soon many Series were considering HD originated image capture.

In May 2002 *Star Wars Episode II: Attack of the Clones* became the first high-profile, high-budget movie released that was shot on 24 frame-per-second high-definition digital video, using a Sony HDW-F900 camera. Two lesser-known movies, Vidocq (2001) and Russian Ark (2002), had previously been shot with the same camera, the latter notably consisting of a single shot (no cuts).

In parallel with these developments in the world of traditional high-budget cinematography, a digital cinema revolution was occurring from the bottom up, among low budget filmmakers outside of the Hollywood system. Beginning in the mid-1990s, with the introduction of Sony's DCR-VX1000, the digital MiniDV format began to emerge. MiniDV offered much greater quality than the analog formats that preceded it, at the same price point. While its quality was not considered as good as film, these MiniDV camcorders, in conjunction with non-linear editing software that could run on personal computers, allowed a large number of people to begin making movies who were previously prevented from doing so by the high costs involved with shooting on film.

Today, cameras from companies like Sony, Panasonic, JVC and Canon offer a variety of choices for shooting high-definition video with less than $10,000 worth of camera equipment. Additionally, some digital SLR photo cameras from vendors like Canon and Nikon have started adding 24 or 30 frame per second video modes.

At the high-end of the market, there has been an emergence of cameras aimed specifically at the digital cinema market. These cameras from Sony, Vision Research, Arri, Silicon Imaging, Panavision, Grass Valley and Red offer resolution and dynamic range that exceeds that of traditional video cameras, which are designed for the limited resolution and dynamic range of broadcast television.

Technology

Digital cinematography captures motion pictures digitally, in a process analogous to digital photography. While there is no clear technical distinction that separates the images captured in digital cinematography from video, the term "digital cinematography" is usually applied only in cases where digital acquisition is substituted for film acquisition, such as when shooting a feature film. The term is not generally applied when digital acquisition is substituted for analog video acquisition, as with live broadcast television programs.

Sensors

Digital cinematography cameras capture images using CMOS or CCD sensors, usually in one of two arrangements.

Single chip cameras designed specifically for the digital cinematography market often use a single sensor (much like digital photo cameras), with dimensions similar in size to a 16 or 35 mm film frame or even (as with the Vision 65) a 65 mm film frame. An image can be projected onto a single large sensor exactly the same way it can be projected onto a film frame, so cameras with this design can be made with PL, PV and similar mounts, in order to use the wide range of existing high-end cinematography lenses available. Their large sensors also let these cameras achieve the same shallow depth of field as 35 or 65 mm motion picture film cameras, which is important because many cinematographers consider selective focus an essential visual tool.

Other cameras use three 1/3" or 2/3" sensors in conjunction with a prism, with each sensor capturing a different color. Camera vendors like Sony and Panasonic, have leveraged their experience with these designs into three-chip products targeted specifically at the digital cinematography market. The Thomson Viper also uses a three-chip design. These designs offer benefits in terms of color separation, and rolling shutter, but are incompatible with traditional cinematography lenses and are incapable of achieving 35 mm depth of field unless used with depth-of-field adaptors, which result in some loss of light. New lines of high-end lenses such as the Zeiss DigiPrimes have been developed with these cameras in mind.

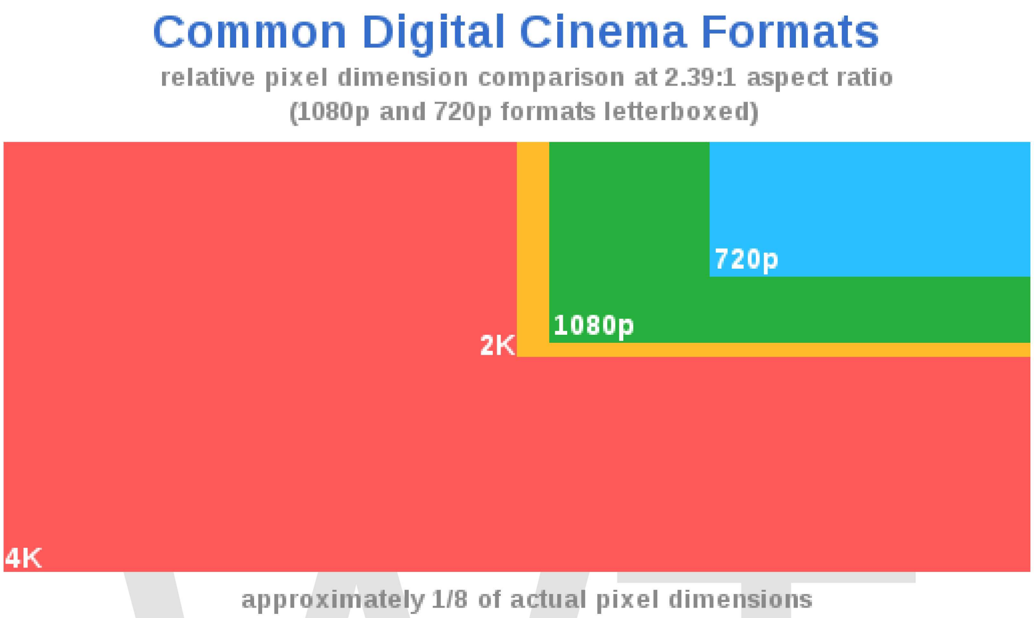
Video Formats

Unlike other video formats, which are specified in terms of vertical resolution (e.g. 1080p, which is 1920x1080 pixels), digital cinema formats are usually specified in terms of horizontal resolution. As a shorthand, these resolutions are often given in "***n*K**" notation, where *n* is the multiplier of 1024 such that the horizontal resolution of a corresponding *full-aperture*, digitized film frame is exactly 1024*n* pixels. Here the 'K' has a customary, improper meaning: it should be the binary prefix "kibi" (ki) instead.

For instance, a 2K image is 2048 pixels wide, and a 4K image is 4096 pixels wide. Vertical resolutions vary with aspect ratios though; so a 2K image with a HDTV (16:9) aspect ratio is 2048x1152 pixels, while a 2K image with a SDTV or Academy ratio (4:3) is 2048x1536 pixels, and one with a Panavision ratio (2.39:1) would be 2048x856 pixels, and so on. Due to the "*n*K" notation not corresponding to specific horizontal resolutions per format a 2K image lacking, for example, the typical 35mm film soundtrack space, is only 1828 pixels wide, with vertical resolutions rescaling accordingly. This led to a plethora of motion-picture related video resolutions, which is quite confusing and often redundant with respect to nowadays few projection standards.

All formats designed for digital cinematography are progressive scan, and capture usually occurs at the same 24 frame per second rate established as the standard for 35mm film.

The DCI standard for cinema usually relies on a 1.89:1 aspect ratio, thus defining the maximum container size for 4K as 4096x2160 pixels and for 2K as 2048x1080 pixels (either 24fps or 48fps). When distributed in the form of a Digital Cinema Package (DCP), content is letterboxed or pillarboxed as appropriate to fit within one of these container formats.



In the last few years, 2K has been the most common format for digitally acquired major motion pictures however, as new camera systems gain acceptance, 4K is becoming more prominent (as the 1080p format has been before). During 2009 at least two major Hollywood films, *Knowing* and *District 9*, were shot in 4K on the RED ONE camera, as well as The Social Network in 2010.

Data Storage

Broadly, there are two paradigms used for data acquisition and storage in the digital cinematography world.

Tape-based workflows

With video tape based workflow video is recorded to video tape on set. This video is then ingested into a computer running non-linear editing software, using a deck. Upon ingestion, a digital video stream from tape is converted to computer files. These files can be edited directly or converted to an intermediate format for editing. Then video is output in its final format, possibly to a film recorder for theatrical exhibition, or back to video tape for broadcast use. Original video tapes are kept as an archival medium. The files generated by the non-linear editing application contain the information necessary to retrieve footage from the proper tapes, should the footage stored on the computer's hard disk be lost.

File-based workflows

Digital cinematography is gradually shifting towards "tapeless" or "file-based" workflow. This trend has accelerated with increased capacity and reduced cost of non-linear storage solutions like hard disk drives, optical discs and solid-state memory. With tapeless workflow digital video is recorded as digital files onto random-access media like optical discs, hard disk drives or flash memory-based digital "magazines". These files can be easily copied to another storage device, typically to a large RAID connected to an editing system. Such RAID arrays, both of "managed" (e.g. SANs and NASs) and "unmanaged" (e.g. JBoDs) type, are necessary due to the enormous throughput required for real-time (320 MB/s for 2K @ 24fps) or near-real-time playback in post-production, compared to one from a single, yet fast, hard disk drive. Such requirements are often termed as "on-line" storage. Post-production not requiring real-time playback performances (typical for lettering, subtitling, versioning and other similar visual effects) can be settled on slightly slower RAID storages. Once data is copied from the digital magazines, they are erased and returned to the set for more shooting.

Short-term archival, *if ever*, is accomplished by moving the digital files into "slower" RAID arrays (still of either managed and unmanaged type, but with lower performances), where playback capability is poor to inexistent (unless via proxy images), but minimal editing and metadata harvesting still feasible. Such intermediate requirements easily fall into the "mid-line" storage category. Long-term archival is accomplished by backing up the digital files from the RAID, using standard practices and equipment for data backup from the IT industry, often to data tapes (like LTOs).

Compression

Digital cinema cameras are capable of generating extremely large amounts of data; often hundreds of megabytes per second .To help manage this huge data flow, many cameras or recording devices designed to be used in conjunction with them offer compression. Prosumer cameras typically use high compression ratios in conjunction with chroma subsampling. While this allows footage to be comfortably handled even on fairly modest personal computers, the convenience comes at the expense of image quality.

High-end digital cinematography cameras or recording devices typically support recording at much lower compression ratios, or in uncompressed formats. Additionally, digital cinematography camera vendors are not constrained by the standards of the consumer or broadcast video industries, and often develop proprietary compression technologies that are optimized for use with their specific sensor designs or recording technologies.

Lossless vs. lossy compression

A lossless compression system is capable of reducing the size of digital data in a fully reversible way—that is, in a way that allows the original data to be completely restored, byte for byte. This is done by removing redundant information from a signal. Digital cinema cameras rarely use only lossless compression methods, because much higher compression ratios (lower data rates) can be achieved with lossy compression. With a lossy compression scheme, information is discarded to create a simpler signal. Due to limitations in human visual perception, it is possible to design algorithms which do this with little visual impact.

Chroma subsampling

Most digital cinematography systems further reduce data rate by subsampling color information. Because the human visual system is much more sensitive to luminance than to color, lower resolution color information can be overlaid with higher resolution luma (brightness) information, to create an image that looks very similar to one in which both color and luma information are sampled at full resolution. This scheme may cause pixelation or color bleeding under some circumstances. High quality digital cinematography systems are capable of recording full resolution color data (4:4:4) or raw sensor data.

Bitrate

Video and audio compression systems are often characterized by their bitrates. Bitrate describes how much data is required to represent one second of media. One cannot directly use bitrate as a measure of quality, because different compression algorithms perform differently. A more advanced compression algorithm at a lower bitrate may deliver the same quality as a less advanced algorithm at a higher bitrate.

Intra- vs. Inter-frame compression

Most compression systems used for acquisition in the digital cinematography world compress footage one frame at a time, as if a video stream is a series of still images. This is called intra-frame compression. Inter frame compression systems can further compress data by examining and eliminating redundancy between frames. This leads to higher compression ratios, but displaying a single frame will usually require the playback system to decompress a number of frames from before & after it. In normal playback this is not a problem, as each successive frame is played in order, so the preceding frames have already been decompressed. In editing, however, it is common to jump around to specific frames and to play footage backwards or at different speeds. Because of the need to decompress extra frames in these situations, inter-frame compression can cause performance problems for editing systems. Inter-frame compression is also disadvantageous because the loss of a single frame (say, due to a flaw writing data to a tape) will typically ruin all the frames until the next keyframe occurs. In the case of the HDV format, for instance, this may result in as many as 6 frames being lost with 720p recording, or 15 with 1080i recording . An inter-frame compressed video stream consists of groups of pictures (GOPs), each of which has only one full frame, and a handful of other frames referring to this frame. If the full frame, called I-frame, is lost due to transmission or media error, none of the P-frames of B-frames (the referenced images) can be displayed. In this case, the whole GOP is lost.

Digital acquisition codecs compared

Format	Bit depth	Resolution	Chroma sampling	Bitrate	File size	Inter-frame?	Algorithm type
DV	8 bits	720×480 (NTSC), 720×576 (PAL)	4:1:1 or 4:2:0	25 Mb/s	217 MB/min.	No	DCT (lossy)
DVCPRO50	8 bits	720×480 (NTSC), 720×576 (PAL)	4:2:2	50 Mb/s	423 MB/min.	No	DCT (lossy)
AVCHD	8 bits	1920x1080, 1440x1080, 1280x720	4:2:0	24 Mb/s		Yes	DCT (lossy)
AVC Intra	10 bits	1920x1080, 1440x1080, 1280x720	4:2:2	50 or 100 Mb/s		No	DCT (lossy)
HDV	8 bits	1280×720, 1440×1080	4:2:0	19-25 Mb/s	142 MB/min. (720p), 190 MB/min. (1080i)	Yes	DCT (lossy)
XDCAM HD422	8 bits	1280x720, 1920×1080	4:2:2	50 Mb/s		Yes	DCT (lossy)
XDCAM EX	8 bits	1280x720, 1920×1080, 1440×1080	4:2:0	25-35 Mb/s	190 MB/min., 262 MB/min.	Yes	DCT (lossy)
DVCPRO HD	8 bits	960×720, 1280×1080, 1440×1080	4:2:2	100 Mbit/s	423 MB/min. (720p60), 835 MB/min. (1080i60)	No	DCT (lossy)
HDCAM	8 bits	1440×1080	3:1:1	144 Mb/s		No	DCT (lossy)
HDCAM SR	10 bit	1920×1080	4:2:2 or 4:4:4	440 or 880 Mb/s		No	DCT (lossy)
Panavision SSR	10-bit PanaLog	1920×1080	4:2:2 or 4:4:4	up to 3 Gb/s		No	Uncompressed

CineForm RAW (SI-2K)	10-bit Log	2048×1152	Raw Bayer	100-140 Mb/s	900 MB/min.	No	Wavelet (lossy)
REDCODE RAW	12 bits	4520x2540, 4480×1920, 4096×2304	Raw Bayer	224-336 Mb/s	1.6-2.5 GB/min.	No	Wavelet (lossy)
ARRIRAW	12 bits	2880×2160	Raw Bayer	~ 5.6 Gb/s	42 GB/min.	No	Uncompressed
"DALSA" RAW	16 bits	4096×2048	Raw Bayer	~ 3.2 Gb/s		No	Uncompressed

Distribution Formats

Movies shot digitally may be released theatrically, on DVD or in a High Definition format like Blu-Ray.

Digital Theatrical Distribution

For the over 4,000 theaters with digital projectors in the USA, digital films may be distributed digitally, either shipped to theaters on hard drives or sent via the Internet or satellite networks. Digital Cinema Initiatives, LLC, a joint venture of Disney, Fox, MGM, Paramount, Sony Pictures Entertainment, Universal and Warner Bros. Studios, has established standards for digital cinema projection. In July 2005, they released the first version of the Digital Cinema System Specification, which encompasses 2K and 4K theatrical projection. They also offer compliance testing for exhibitors and equipment suppliers.

Distributors prefer digital distribution, because it saves them the expense of making film prints, which may cost as much as $2000 each. Digital projection also offers advantages over traditional film projection such as lack of jitter, flicker, dust, scratches, and grain.

Theater owners initially balked at installing digital projection systems because of high cost and concern over increased technical complexity. However new funding models, in which distributors pay a "digital print" fee to theater owners, have helped to alleviate these concerns. Digital projection also offers increased flexibility with respect to showing trailers and pre-show advertisements and allowing theater owners to more easily move films between screens or change how many screens a film is playing on, and the higher quality of digital projection provides a better experience to help attract consumers who can now access high-definition content at home. These factors have resulted in digital projection becoming an increasingly attractive prospect for theater owners, and the pace of adoption has increased.

In the UK 300 cinema screens were converted to digital projectors as part of a UK film council initiative, the Digital Screen Network (DSN) to advance digital theatrical distribution in the UK funded by National lottery money. The first film to be screened digitally on the DSN was King's Game, a Danish film.

Film-based Theatrical Distribution

Since not all theaters currently have digital projection systems, even if a movie is shot and post-produced digitally, it must be transferred to film if a large theatrical release is planned. Typically, a film recorder will be used to print digital image data to film, to create a 35 mm internegative. After that the duplication process is identical to that of a traditional negative from a film camera.

Digital cinematography cameras

Professional cameras include the Sony HDCAM Series, RED ONE, Arriflex D-20 and D-21, Panavisions Genesis, Silicon Imaging SI-2K, Thomson Viper, Vision Research Phantom, Weisscam HS-1 and HS-2, GS Vitec noX, and the Fusion Camera System. Independent filmmakers have also pressed low-cost consumer and prosumer cameras into service for digital filmmaking.

Digital vs. film cinematography

Technical considerations

Predictability

When shooting on film, response to light is determined by what film stock is chosen. A cinematographer can choose a film stock he is familiar with, and expose film on set with a high degree of confidence about how it will turn out. Because the film stock is the main determining factor, results will be substantially similar regardless of what camera model is being used. In contrast, when shooting digitally, response to light is determined by the CMOS or CCD sensor(s) in the camera, so the cinematographer needs familiarity with the specific camera model.

With digital cinematography, however, on-set monitoring allows the cinematographer to see the actual images that are captured, immediately on the set, which is impossible with film. With a properly calibrated high-definition display, on-set monitoring, in conjunction with data displays such as histograms, waveforms, RGB parades, and various types of focus assist, can give the cinematographer a far more accurate picture of what is being captured than is possible with film, where a final image cannot be viewed until the film stock is processed. However, some of this equipment may impose costs in terms of time and money, and may not be possible to utilize in difficult shooting situations.

Film cameras do often have a video assist that captures video through the camera lens to allow for on-set playback, but its usefulness is largely restricted to judging action and framing. Because this video is not derived from the image that is actually captured to film, it is not very useful for judging lighting, and because it is typically only NTSC-resolution, it is often useless for judging focus.

Portability

35 mm film cameras cannot be sized down below a certain size and weight, as they require space for a film magazine and a film transport mechanism that have a minimum size effectively determined by the physical size of the film. While some digital cinematography cameras are large and bulky, even compared to full-sized film cameras, others are extremely compact, and offer features such as the ability to detach the camera head from the rest of the camera, allowing high quality images to be captured with an extremely compact package. The tapes, hard drives and flash memory magazines that digital cameras record onto are also far more compact than the film magazines used by film cameras. These factors can result in substantial portability advantages for digital cinematography systems.

Dynamic Range

The sensors in most high-end digital video cameras have less exposure latitude (dynamic range) than modern motion picture film stocks. In particular, they tend to 'blow out' highlights, losing detail in very bright parts of the image. If highlight detail is lost, it is impossible to recapture in post-production. Cinematographers can learn how to adjust for this type of response using techniques similar to those used when shooting on reversal film, which has a similar lack of latitude in the highlights. They can also use on-set monitoring and image analysis to ensure proper exposure. In some cases it may be necessary to 'flatten' a shot, or reduce the total contrast that appears in the shot, which may require more lighting to be used.

Some more recent digital cinema cameras attempt to more closely emulate the way film handles highlights and are used by many high-budget productions intercut with film. A few cinematographers have started deliberately using the 'harsh' look of digital highlights for aesthetic purposes. One notable example of such use is *Battlestar Galactica*.

Digital acquisition typically offers better performance than film in low-light conditions, allowing less lighting and in some cases completely natural or practical lighting to be used for shooting, even indoors. This low-light sensitivity also tends to bring out shadow detail.

Resolution

Substantive debate over the subject of film resolution vs. digital image resolution is clouded by the fact that it is difficult to meaningfully and objectively determine the resolution of either. However the huge majority of all blockbuster-movie of the first decade of the 21st century have been finished in 2K - which can easily be surpassed by mechanical as well as digital camera systems.

Unlike a digital sensor, a film frame does not have a regular grid of discrete pixels. Rather, it has an irregular pattern of differently sized grains. As a film frame is scanned at higher and higher resolutions, image detail is increasingly masked by grain, but it is difficult to determine at what point there is no more useful detail to extract. Moreover, different film stocks have widely varying ability to resolve detail.

Determining resolution in digital acquisition seems straightforward, but is significantly complicated by the way digital camera sensors work in the real world. This is particularly true in the case of high-end digital cinematography cameras that use a single large bayer pattern CMOS sensor. A bayer pattern sensor does not sample full RGB data at every point; each pixel is biased toward red, green *or* blue , and a full color image is assembled from this checkerboard of color by processing the image through a demosaicing algorithm. Generally with a bayer pattern sensor, actual resolution will fall somewhere between the "native" value and half this figure, with different demosaicing algorithms producing different results. Additionally, most digital cameras (both bayer and three-chip designs) employ optical low-pass filters to avoid aliasing. Such filters reduce resolution.

In general, it is widely accepted that an original film camera negative exceeds the resolution of HDTV formats and the 2K digital cinema format, but there is still significant debate about whether 4K digital acquisition can match the results achieved by scanning 35 mm film at 4K, as well as whether 4K scanning actually extracts all the useful detail from 35 mm film in the first place. However, from 2000 to 2009, the overwhelming majority of films that used a digital intermediate were mastered at 2K, independent of their budget. Additionally, 2K projection is chosen for most permanent digital cinema installations, often even when 4K projection is available.

One important thing to note is that the process of optical duplication, used to produce theatrical release prints for movies that originate both on film and digitally, causes significant loss of resolution. If a 35 mm negative does capture more detail than 4K digital acquisition, ironically this may only be visible when a 35 mm movie is scanned and projected on a 4K digital projector. The most limiting factor when not using digital cinema however is the end of the exhibition chain: For mechanical projection, the SMPTE allows flutter and weave up to 0.2%, which reduces projected resolution down to 1K. Well maintained mechanical projectors however can operate at 0.05%, which can almost reach 2K resolution.

Grain & noise

Film has a characteristic grain structure. Different film stocks have different grain, and cinematographers may use this for artistic effect.

Digitally acquired footage lacks this grain structure. Electronic noise is sometimes visible in digitally acquired footage, particularly in dark areas of an image or when footage was shot in low lighting conditions and gain was used.

Since most theatrical exhibition still occurs via film prints, the clean look of digital acquisition is often lost before moviegoers get to see it, because most major releases are in the 35mm film format and all film stocks have film grain.

Digital Intermediate Workflow

The process of using digital intermediate workflow, where movies are color graded digitally instead of via traditional photochemical finishing techniques, has become common, largely because of the greater artistic control it provides to filmmakers. In 2007, all of the 10 most successful movies released used the digital intermediate process.

In order to utilize digital intermediate workflow with film, the camera negative must first be processed and then scanned to a digital format. High quality film scanning is expensive (up to $4 a frame, although the costs of this are continually dropping). With digital acquisition, the scanning step is not necessary. Footage can go directly into a digital intermediate pipeline as digital data, although with some digital acquisition systems, it may need to be processed into suitable formats before it can be worked with.

Some filmmakers have years of experience achieving their artistic vision using the techniques available in a traditional photochemical workflow, and prefer that finishing/editing process. While it would be theoretically possible to use such a process with digital acquisition by creating a film negative on a film recorder, in general digital acquisition is not a suitable choice if a traditional finishing process is desired. However, traditional photochemical finishes have become extremely rare for Hollywood features.

Sound

Films are traditionally shot with dual-system recording, where picture is recorded on camera, and sync sound is recorded to a separate sound recording device. Picture and sound are then synced up in post-production. In the past this was done manually by lining up the image of the just-closed clapper board sticks with their characteristic clap on the sound recording. Today it is often done automatically using timecode data burnt onto the edge of the film emulsion and timecode displayed on digital clapper slates.

Most cameras used for digital cinematography can record sound internally, already in sync with picture. In theory this eliminates the need for syncing in post, which can lead to faster workflows. However, most sound recording is done by specialist operators, and the sound will likely be separated and further processed in post-production anyway. Moreover, high-end dedicated audio recording devices typically can record better quality sound than the audio recording subsystems of cameras, so most higher end production uses dual system recording even with cameras that are capable of recording sound internally. On such productions, internal camera audio may be used to record "scratch tracks" as an aid to the editor when syncing with the separately recorded master audio, to allow footage to be edited or viewed with sound prior to being synced with the master audio, or as a backup in case something is wrong with the master audio. Like modern film cameras, digital cinematography cameras can typically accept timecode data from external devices and record it with each frame of footage. Digital clapper slates are also commonly used.

Archiving

Some studios opt for a film negative master for archival purposes. There are after all numerous extant examples of original 19th century film footage which were manufactured under primitive conditions, with no consideration given to archival value, but whose original images are still clearly visible and recoverable with relatively simple equipment. As long as the negative does not completely degrade, it will always be possible to recover the images from it in the future, regardless of changes in technology, since all that will be involved is simple photographic reproduction. In contrast, even if digital data is stored on a medium that will preserve its integrity, highly specialized digital equipment will always be required to reproduce it. Changes in technology may thus render the format unreadable or expensive to recover over time. For this reason, film studios distributing digitally-originated films often make film-based separation masters of them for archival purposes.

Economics

Low-budget / Independent Filmmaking

For the last 25 years, many respected filmmakers like George Lucas have predicted that electronic or digital cinematography would bring about a revolution in filmmaking, by dramatically lowering costs.

For low-budget and so-called "no-budget" productions, digital cinematography on prosumer cameras clearly has cost benefits over shooting on 35 mm or even 16 mm film. The cost of film stock, processing, telecine, negative cutting, and titling for a feature film can run to tens of thousands of dollars according to *From Reel to Deal*, a book on independent film production by Dov S-S Simens, based on his 2-day film course. Costs directly attributable to shooting a low-budget feature on 35 mm film could be $50,000 on the low side, and over twice that on the high side. In contrast, obtaining a high-definition prosumer camera and sufficient tape stock to shoot a feature can easily be done for under $10,000, or significantly less if, as is typically the case with 35 mm shoots, the camera is rented.

Most extremely low-budget movies never receive wide distribution, so the impact of low-budget video acquisition on the industry remains to be seen. It is possible that as a result of new distribution methods and the long tail effects they may bring into play, more such productions may find profitable distribution in the future. Traditional distributors may also begin to acquire more low-budget movies as better affordable digital acquisition eliminates the liability of low picture quality, and as they look for a means to escape the increasingly drastic "boom and bust" financial situation created by spending huge amounts of money on a relatively small number of very large movies, not all of which succeed.

On higher budget productions, the direct cost advantages of digital cinematography are not as significant in relation to the total budget, primarily because the costs imposed by working with film typically account for no more than a few percent of such large budgets.

Digital acquisition, however, offers numerous significant advantages on high-budget shoots, such as the ability to work faster (with fewer magazine changes and less concern over shooting large amounts of footage), to back up footage on set for additional safety, and to check important shots immediately, potentially avoiding costly reshoots. Digital workflow may also allow shots to be delivered to post production pipelines for color grading, visual effects work or editorial assembly even before principle photography ends. Some of these functions may even be performed on set so that, for instance, if a cinematographer has a specific stylized look in mind for color grading, he or she can see almost immediately how footage will appear with that look applied, and take this into account while shooting it.

Rick McCallum, a producer on *Star Wars Episode II: Attack of the Clones*, has commented that the production spent $16,000 for 220 hours of digital tape, where a comparable amount of film would have cost $1.8 million. However, this does not necessarily indicate the actual cost savings percentage, as the very low incremental cost of shooting additional footage may encourage filmmakers to use far higher shooting ratios with digital.

Industry acceptance of digital cinematography

Throughout the 20th century however, virtually all movies were shot on film, and back then nearly every film student learned about how to handle 16 mm and 35 mm film. While many major motion pictures are still shot on film, digital cinematography has gained widespread acceptance over the last few years and is gaining market share year by year.

Digital cinematography accounts for a larger fraction of feature movie shooting every year, especially in A-budget productions, and seems destined to eventually eclipse film-based acquisition, much as digital photo cameras have largely replaced film based photo cameras in the still photography world. The majority of American episodic TV-series already are produced digitally.

Sales of digital cinema camera have massively surpassed mechanical cameras sales since 2007. The once market-leading manufacturers of mechanical cameras, panavisison, arri and aaton, have only introduced and developed digital cinema cameras since then. All newly introduced cinema cameras since 2007 are digital. All new manufacturers of cinema cameras, silicon imaging, red, Sony, vision research only offer digital cameras. The Academy Award for Best Cinematography have been won by movies shot completely or mostly digitally in 2009 and 2010.

In 2009, the Academy Award for Best Cinematography was awarded for a movie mostly shot digitally, *Slumdog Millionaire*. Another nominee, *The Curious Case of Benjamin Button*, was also shot digitally.

Some notable high-profile directors and producers that have shot with digital equipment include:

- Robert Altman – *A Prairie Home Companion*
- Jean-Jacques Annaud – *Two Brothers, His Majesty Minor*
- Danny Boyle – *Slumdog Millionaire*, *28 Days Later*
- James Cameron – *Ghosts of the Abyss*, *Aliens of the Deep*, *Avatar*
- Francis Ford Coppola – *Youth Without Youth*, *Tetro*
- David Fincher – *Zodiac*, *The Curious Case of Benjamin Button*
- Mel Gibson – *Apocalypto*
- Anthony Hopkins – *Slipstream*
- Peter Jackson – *Crossing the Line*, *The Lovely Bones*
- Spike Lee – *Bamboozled*
- Aditya Chopra - *Rab Ne Bana Di Jodi*
- Frank Miller - *The Spirit*
- Joe Dante – *The Hole*
- Rob Marshall - *Pirates of the Caribbean: On Stranger Tides*
- George Lucas – *Star Wars Episode II: Attack of the Clones*, *Star Wars Episode III: Revenge of the Sith*
- Peter Segal - *Get Smart*
- Karan Johar - *My Name Is Khan*
- Guy Ritchie - *RocknRolla*
- Sidney Lumet – *Before the Devil Knows You're Dead*
- David Lynch – *Inland Empire*
- Michael Mann – *Miami Vice*, *Collateral, Public Enemies*
- Rob Minkoff – *The Forbidden Kingdom*
- Hughes brothers - *The Book of Eli*
- Michael Moore – *Bowling for Columbine*
- Greg Mottola – *Superbad*
- Doug Liman – *Jumper*, *Fair Game*
- Peter Greenaway – *Nightwatching*
- Pitof – *Vidocq*
- Alex Proyas – *Knowing*
- Oliver Stone - *Comandante, Looking for Fidel*
- Robert Rodriguez – *Sin City*, *Grindhouse, Spy Kids 3-D: Game Over, Once Upon a Time in Mexico*
- Tony Scott – *Déjà Vu*
- Larry Charles - *Religulous*
- Ridley Scott - *The Company*
- Roger Donaldson - *The Bank Job*
- Bryan Singer – *Superman Returns*
- Bruce Willis - *Three Stories About Joan*

- Steven Soderbergh – *Che*, *The Girlfriend Experience*
- Lee Tamahori – *Next*
- Lars von Trier – *Dogville*, *Manderlay*, *Antichrist*
- Martin Scorsese - *Shine a Light, George Harrison Documentary*, *Hugo Cabret*
- Andy Wachowski and Larry Wachowski – *Speed Racer*
- David Zucker – *Scary Movie 4*

Some directors have expressed an openness for either format, such as Jean-Jacques Annaud who used 35 mm and HDCAM together for Two Brothers , or Quentin Tarantino, who, while he ended up shooting his contribution on film, expressed an interest in digital acquisition for Grindhouse. Tarantino, however, has also indicated that he would continue shooting Grindhouse on film .

Other filmmakers haven't directed digitally acquired films, but have produced them. For instance, Ridley Scott produced the 2007 series "The Company," which was shot on the Arri D-20.

Lower-budget and limited-release movies have adopted digital cinematography at a somewhat faster pace, although some filmmakers still choose to shoot such productions on 16 mm film, the traditional medium for that market segment.

As the digital intermediate process gains wider use for finishing movies shot on film, and as digital acquisition technology continues to improve, it seems likely digital cinematography will continue to gain wider acceptance.

Digital technology has eclipsed analog alternatives in many other content creation and distribution markets. On the content creation side, digital photo cameras significantly outsell film photo cameras, digital video tape formats like MiniDV have superseded analog tape formats, digital audio workstations have almost entirely replaced multi-track tape recorders, digital non-linear editing systems have displaced Moviola/Steenbeck equipment as the standard means of editing movies, and page layout software running on desktop computers has come to dominate the graphic design industry. On the distribution side, CDs have largely replaced LPs, DVDs have largely replaced VHS tapes, and digital cable systems are displacing analog cable systems. According to all major manufacturers of cameras it seems likely that despite resistance on the part of some few users in the industry, digital technology will eventually be similarly successful in the feature film acquisition and theatrical exhibition markets. In the exhibition market of the USA, the three market leading chains, AMC, Regal and Cinemark are converting all of their cinemas to digital since 2009. According to their business plans 2012 the process shall be completed and the majority of all American cinemas then will be digital.

Chapter- 2

Digital Cinema

Digital cinema refers to the use of digital technology to distribute and project motion pictures. A movie can be distributed via hard drives, optical disks (such as DVDs) or satellite and projected using a digital projector instead of a conventional film projector. Digital cinema is distinct from high-definition television and, in particular, is not dependent on using television or HDTV standards, aspect ratios, or frame rates. Digital projectors capable of 2K resolution began deploying in 2005, and since 2006, the pace has accelerated (2K refers to images with 2,048 pixels of horizontal resolution).

Technology

To match or improve the theater experience of movie audiences, a digital cinema system must provide high-quality image and sound. Additionally, theater managers require server controls for managing and displaying content in multiple theaters, and studios want their content encrypted with secure delivery, playback, and reporting of play times to the distribution company.

Digital Cinema Initiatives (DCI), a joint venture of the six major studios, published a system specification for digital cinema. Briefly, the specification calls for picture encoding using the ISO/IEC 15444-1 "JPEG2000" (.jp2) standard and use of the CIE XYZ color space at 12 bits per component encoded with a 2.6 gamma applied at projection, and audio using the "Broadcast Wave" (.wav) format at 24 bits and 48 kHz or 96 kHz sampling, controlled by an XML-format Composition Playlist, into an MXF-compliant file at a maximum data rate of 250 Mbit/s. Details about encryption, key management, and logging are all discussed in the specification as are the minimum specifications for the projectors employed including the color gamut, the contrast ratio and the brightness of the image. While much of the specification codifies work that had already been ongoing in the Society of Motion Picture and Television Engineers (SMPTE), the specification is important in establishing a content owner framework for the distribution and security of first-release motion picture content.

Digital cinema conforming to the DCI Standard is referred to within the film industry as D-Cinema while all other forms of digital cinema are referred to as E-Cinema. Thus, while D-Cinema is a defined standard, though one that is still partly being framed by SMPTE as of 2007, E-Cinema may be anything, ranging from a DVD player connected to a consumer projector to something that approaches the quality of D-Cinema without conforming to some of the standards. Even D-Cinema itself has evolved over time before the DCI standards were framed. However, the current DCI standards were made with the intention of standing the test of time, much like 35 mm film which has evolved but still retained compatibility over a substantial part of a century.

In addition to DCI's work, the National Association of Theatre Owners (NATO) released its Digital Cinema System Requirements. The document addresses the requirements of digital cinema systems from the operational needs of the exhibitor, focusing on areas not addressed by DCI, including access for the visually impaired and hearing impaired, workflow inside the cinema, and equipment interoperability. In particular, NATO's document details requirements for the Theatre Management System (TMS), the governing software for digital cinema systems within a theatre complex, and provides direction for the development of security key management systems. As with DCI's document, NATO's document is also important to the SMPTE standards effort.

Digital capture

As of 2009, the most common acquisition medium for digitally projected features is 35 mm film scanned and processed at 2K (2048×1080) or 4K (4096×2160) resolution via digital intermediate. Most digital features to date have been shot at 1920x1080 HD resolution using cameras such as the Sony CineAlta, Panavision Genesis or Thomson Viper. New cameras such as the Arri Alexa can capture 2K resolution images, and the Red Digital Cinema Camera Company's Red One can record 4K. The marketshare of 2K projection in digital cinemas is over 98%. Currently in development are other cameras capable of recording 4K RAW, such as Dalsa Corporation's *Origin* and Canon's 4K "Multipurpose", and cameras capable of recording 5K, such as the RED EPIC, and cameras capable of recording 3K (for budget filmmakers) such as the RED SCARLET.

Digital post-production

In the post-production process, camera-original film negatives (the film that physically ran through the camera) are scanned into a digital format on a scanner or high-resolution telecine. Data from digital motion picture cameras may be converted to a convenient image file format for work in a facility. All of the files are 'conformed' to match an edit list created by the film editor, and are then color corrected under the direction of the film's staff. The end result of post-production is a digital intermediate used to record the motion picture to film and/or for the digital cinema release.

Digital mastering

When all of the sound, picture, and data elements of a production have been completed, they may be assembled into a *Digital Cinema Distribution Master* (DCDM) which contains all of the digital material needed for projection. The images and sound are then compressed, encrypted, and packaged to form the *Digital Cinema Package* (DCP).

Digital projection

There are currently two types of projectors for digital cinema. Early DLP projectors, which were deployed primarily in the U.S., used limited 1280×1024 resolution or the equivalent of 1.3 MP (megapixels). They are still widely used for pre-show advertising but not usually for feature presentations. The DCI specification for digital projectors calls for two levels of playback to be supported: 2K (2048×1080) or 2.2 MP at 24 or 48 frames per second, and 4K (4096×2160) or 8.85 MP at 24 frames per second.

Three manufacturers have licensed the DLP Cinema technology developed by Texas Instruments (TI): Christie Digital Systems, Barco, and NEC. Christie, long established in traditional film projector technology, is the maker of the CP2000 line of projectors—the most widely deployed platform globally (approximately 5,500 units in total). Barco launched the DP-series of 2K DCI-compliant Digital cinema projectors; next to this Barco designs and develops visualization products for a variety of selected professional markets. NEC currently manufactures the Series II NC1200C, NC2000C and NC3200S 2K projectors for large, medium and small screen respectively, and the NC3240 in 2011 to represent the first generation 4k NEC DCI projector. Starus Digital Cinema Server system, as well as other equipment to connect PCs, analog/digital tape decks and satellite receivers, DVD, and off-air broadcast, etc. for pre-show and special presentations. While NEC is a relative newcomer to Digital Cinema, Christie is the main player in the U.S. and Barco takes the lead in Europe and Asia. In addition Digital Projection Incorporated (DPI) designed and sold a few DLP Cinema units when TI's 2K technology first debuted but then abandoned the D-Cinema market while continuing to offer DLP-based projectors for non-cinema purposes. Although based on the same 2K TI "light engine" as those of the major players they are so rare as to be virtually unknown in the industry. As of January, 2009, there are more than 6,000 DLP-based Digital Cinema systems installed worldwide, of which 80% are located in North America.

The other technology is made by Sony and is labeled "SXRD"(LCOS) technology. The projectors, SRXR220 and SRXR320, offer 4096x2160 (4K) resolution and produce four times the number of pixels of 2K projection. Included in the system is a playback server (LMT-300) along with the ability to show alternative content through the system's 2 input options. Sources could be anything from a Bluray player to satellite feeds, yet Sony's systems are priced competitively with the lower resolution 2048x1080 (2K) or 2.2 MP (megapixels) DLP projectors.

Other manufacturers have been developing digital projector technology, but these have not yet been deployed into cinemas and are not commercially available in versions that conform to the DCI specification.

Live broadcasting to cinemas

Digital cinemas can deliver live broadcasts from performances or events. For example, there are regular live broadcasts to movie theaters of Metropolitan Opera performances.

In February 2009, Cinedigm screened the first live multi-region 3D broadcast through a partnership with TNT. Previous attempts have been isolated to a small number of screens.

Recent developments

In February 2005, Arts Alliance Media was selected to roll out the UK Film Council's Digital Screen Network (DSN), a $20M contract to install and operate Europe's largest 2K digital cinema network. By March 2007, 230 of the 241 screens had been installed on schedule, with the remaining 11 to be installed later in 2007 when cinemas have completed building works or construction.

In China, an E-Cinema System called "dMs" was established on June 2005, and is used in over 15,000 screens spread across China's 30 provinces. dMS estimates that the system will expand to 40,000 screens in 2009.

Chicken Little from Disney, with its experimental release of the film in digital 3D, increased the number of projectors using the 2K format. Several digital 3D films surfaced in 2006 and several prominent filmmakers have committed to making their next productions in stereo 3D.

In mid 2006, about 400 theaters have been equipped with 2K digital projectors with the number increasing every month.

In August 2006, the Malayalam digital movie *Moonnamathoral* , produced by Mrs. Benzy Martin, was distributed via satellite to cinemas, thus becoming the first Indian digital cinema. This was done by Emil and Eric Digital Films, a company based at Thrissur using the end-to-end digital cinema system developed by Singapore-based DG2L Technologies.

The UK is home to Europe's first DCI-compliant fully digital multiplex cinemas. Odeon Hatfield and Odeon Surrey Quays (London) have a total of 18 digital screens and were both launched on Friday 9 February 2007.

As of March 2007, with the release of Disney's *Meet the Robinsons*, about 600 screens have been equipped with 2K digital projectors that feature Real D Cinema's stereoscopic 3D technology, marketed under the Disney Digital 3-D brand.

In June 2007, Arts Alliance Media announced the first European commercial digital cinema VPF agreements (with Twentieth Century Fox and Universal Pictures).

As of July 2007, there are some cinemas in Singapore showing digital 4K films to public using Sony's 4K digital projector. They are located at Golden Village Cinema in Vivocity (Hall 11), Eng Wah Cinema in Suntec (Hall 3), Shaw Cinema in Bugis (Hall 1 & 3) and at Cathay Cineplex (Hall 7).

In September 2007, Muvico Theaters Rosemont 18 in Rosemont, Illinois became the first theater in North America to have Sony's 4K digital projectors for all 18 screens.

By October 2007, DG2L Technologies was reported to have supplied 1500 Digital Cinema Systems to UFO Moviez Ltd. in India and Europe.

As of October 2007, there are over 5,000 DLP-based Digital Cinema Systems installed.

In March 2009 AMC Theatres announced that it closed on a $315 million deal with Sony to replace all of its movie projectors with 4K digital projectors starting in the second quarter of 2009 and completing in 2012.

In May 2009 Regal Entertainment Group announced a deal with Sony to deploy 4K digital cinema projectors in approximately 1,500 screens.

In June 2009, Cinemark Theatres announced it has selected Barco's 4K DLP digital cinema projectors for installation in 3,000 screens. With this announcement, all three major US movie theater chains (AMC, Regal, and Cinemark) have announced major commitments to deliver digital cinema at the definitive 4K resolution at virtually all of their properties in the United States.

As of June, 2010, there are close to 16,000 digital cinema screens, with over 5000 of them being stereoscopic setups.

Economics

Impact on distribution

Digital distribution of movies has the potential to save money for film distributors. To print an 80-minute feature film can cost US$1,500 to $2,500, so making thousands of prints for a wide-release movie can cost millions of dollars. In contrast, at the maximum 250 megabit-per-second data rate (as defined by DCI for digital cinema), a feature-length movie can be stored on a off the shelf 300 GB hard drive for a minuscule fraction of the cost. In addition hard drives can be returned to distributors for reuse. With several hundred movies distributed every year, the industry could save billions of dollars. The film industry has been dominated by a small number of distributors for many years due to a high barrier of entry for new competition. This is caused by high costs and a lack of access to well-established production and distribution networks. By replacing film prints with hard disks the barrier to entry is significantly reduced, opening the market to much stiffer competition. As competition increases market forces reduce an industry's profit margins and decrease the market share of individual companies. The desire to retain market share is one reason established distributors support the VPF model of digital cinema rollout, which reduces the amount of box office revenue theaters transfer to distributors. As a result the net cost of film production increases and profit margins decrease for all distributors. This works to the advantage of entrenched distributors by making it more difficult for new distributors to gain investors, raise enough capital to enter the market, and gain market share. Prior to the VPF model the digital cinema rollout was stalled (as can be seen by major equipment purchases and future commitments to new equipment during this time); exhibitors acknowledged that they would not purchase equipment to replace projectors since the savings would be seen not by themselves but by distribution companies. The VPF model was created to address this (some claim by Frank Stirling at Boeing - Boeing were involved in digital cinema deployment at that time) and this is successfully did, accelerating the rollout of this technology and with it the reduction of the barrier to entry. Given that digital projectors make low volume distribution at last an economic possibility it is the studios' support of the VPF model that has accelerated the introduction of competition, both in terms of alternative distributors and also alternative content including cinematic series.

Alternative content

An added incentive for exhibitors is the ability to show alternative content such as live special events, sports, pre-show advertising and other digital or video content. Some low-budget films that would normally not have a theatrical release because of distribution costs might be shown in smaller engagements than the typical large release studio pictures. The cost of duplicating a digital "print" is very low, so adding more theaters to a release has a small additional cost to the distributor. Movies that start with a small release could scale to a much larger release quickly if they were sufficiently successful, opening up the possibility that smaller movies could achieve box office success previously out of their reach. Alternate content is also finding a market in 3rd world countries in which the higher costs and quality of DCI equipment are not yet affordable.

Greater protection for content

A last incentive for copyright holders for digital distribution is the possibility of greater protection against piracy. With traditional film prints, distributors typically stagger the film's release in various markets, shipping the film prints around the globe. In the subsequent markets, pirated copies of a film (i.e. a cam) may be available before the movie is released in that market. A simultaneous worldwide release would mitigate this problem to some degree. Simultaneous worldwide releases on film have been used on *The Da Vinci Code*, *Lord of the Rings: Return of the King*, *Star Wars Episode III: Revenge of the Sith*, *Charlie's Angels: Full Throttle* and *Mission: Impossible III* amongst others. With digital distribution, a simultaneous worldwide release would not cost significantly more than a staggered release.

Costs

On the downside, the initial costs for converting theaters to digital are high: up to $150,000 per screen or more. Theaters have been reluctant to switch without a cost-sharing arrangement with film distributors. Recent negotiations have involved the development of a *Virtual Print License* fee which the studios will pay for their products which allows financiers and system developers to pay for deployment of digital systems to the theaters, thus providing investors a certain payback.

While a theater can purchase a film projector for US$50,000 and expect an average life of 30–40 years, a digital cinema playback system including server/media block/and projector can cost 3–4 times as much, and is at higher risk for component failures and technological obsolescence. Experience with computer-based media systems show that average economic lifetimes are only on the order of 5 years with some units lasting until about 10 years before they are replaced.

Archiving digital material is also turning out to be both tricky and costly. In a 2007 study, the Academy of Motion Picture Arts and Sciences found the cost of storing 4K digital masters to be "enormously higher - 1100% higher - than the cost of storing film masters." Furthermore, digital archiving faces challenges due to the insufficient temporal qualities of today's digital storage: no current media, be it optical discs, magnetic hard drives or digital tape, can reliably store a film for a hundred years, something that properly stored and handled film can do.

History

Digital media playback of hi-resolution 2K files has at least a twenty year history with early RAIDs feeding custom frame buffer systems with large memories. Content was usually restricted to several minutes of material.

Transfer of content between remote locations was slow and had limited capacity. It wasn't until the late 1990s that feature length projects could be sent over the 'wire' (Internet or dedicated fiber links).

There were many prototype systems developed that claim a *first* in some form of digital presentation. However, few of these had a significant impact on the advance of the industry. Key highlights in the development of digital cinema would likely include: demonstrations by TI of their DMD technology, real-time playback of compressed hi-resolution files by various vendors, and early HD presentations from D5 tape to digital projectors.

Standards development

The Society of Motion Picture and Television Engineers began work on standards for digital cinema in 2001. It was clear by that point in time that HDTV did not provide a sufficient technological basis for the foundation of digital cinema playback. (In Europe and Japan however, there is still a significant presence of HDTV for theatrical presentations. Agreements within the ISO standards body have led to these systems being referred to as Electronic Cinema Systems (E-Cinema).)

Digital Cinema Initiatives (DCI) was formed in March 2002 as a joint project of many motion picture studios (Disney, Fox, MGM, Paramount, Sony Pictures Entertainment, Universal and Warner Bros. Studios) to develop a system specification for digital cinema. In cooperation with the American Society of Cinematographers, DCI created standard evaluation material (the ASC/DCI StEM material) and developed tests of 2K and 4K playback and compression technologies. DCI published their specification in 2005.

Claims to significant events

One claim for the first digital cinema demonstration comes from JVC. On March 19, 1998, they collaborated on a digital presentation at a cinema in London. Several clips from popular films were encoded onto a remote server, and sent via fibre optic for display to a collection of interested Industry parties.

The Last Broadcast apparently made cinematic history on October 23, 1998, when it became the first feature to be theatrically released digitally, via satellite download to theaters across the United States. An effort headed by Wavelength Releasing, Texas Instruments, Digital Projection Inc. and Loral Space, it successfully demonstrated what would become a template for future releases. In 1999, it was repeated utilizing QuVIS technology across Europe, including the Cannes Film Festival, making *The Last Broadcast* the first feature to be screened digitally at the Cannes Film Festival.

Several feature films were shown in 1999 using DLP prototype projectors and early wavelet based servers. For example, Walt Disney Pictures *Bicentennial Man* was presented using a Qubit server manufactured by QuVIS of Topeka, Kansas. DVD ROM was used to store the compressed data file. The DVD ROMs were loaded into the QuBit server hard drives for playout. The file size for *Bicentennial Man* was 42 GB with an average data rate of 43 Mbit/s.

In 2000, Walt Disney, Texas Instruments and Technicolor with the cooperation of several U.S. and international exhibitors, began to deploy prototype Digital Cinema systems in commercial theatres. The systems were assembled and installed by Technicolor using the TI mark V prototype projector, a special Christie lamphouse, and the QuBit server with custom designed automation interfaces.

On February 2, 2000, Philippe Binant, technical manager of Digital Cinema Project at Gaumont in France, realized the first digital cinema projection in Europe with the TI mark V prototype projector.

Technicolor manufactured the DVDs for uploading on these test systems and was responsible for sending technicians out to the locations for every new feature film that was played. The technicians would typically spend ten or so hours to load the files from the DVD to the QuBit, set up the server to play the files, and then set up the projector. A full rehearsal screening of the feature was mandatory as was the requirement to have back up DVDs and backup QuBits available should something fail.

The systems were eventually replaced or upgraded after TI made improvements to the projectors and Technicolor developed a purpose-built digital cinema server in a venture with Qualcomm. The new systems were called *AMS* for *Auditorium Management Systems* and were the first digital cinema servers designed to be user friendly and operate reliably in a computer-hostile environment such as a projection booth. Most importantly, they provided a complete solution for content security.

The AMS used removable hard disk drives as the transport mechanism for the files. This eliminated the time required to upload the DVD ROMs to the local hard drives and provided the ability to switch programs quickly. For security, the AMS used a media block type system that placed a sealed electronics package within the projector housing. The server output only Triple DES encrypted data and the media block did the decryption at the point just before playout.

The first secure encrypted digital cinema feature was *Star Wars Episode II: Attack of the Clones* by Cinecomm Digital Cinema (then led by Russell J. Wintner). This first digital delivery and exhibition of a full-length feature film to paying audiences is widely considered to be the defining moment for digital cinema's commercial viability. The film was transmitted and then shown digitally in theatres both in Paramus, New Jersey and Los Angeles, California. The system functioned well but was eventually replaced because of the need to create a standard data package for D-cinema distribution.

The First Digital Cinema Network enabling digital delivery directly to the theaters was built by Digital Cinema Solutions in 2002. The company was founded by James Steele. The network was built as a vehicle to play the BMW Film Series The Hire in movie theaters . In a partnership with Microsoft , Steele connected 28 of the top Independent Art Houses in the United States including many Landmark Theaters, The Angelikas in New York and Houston, The Charles in Baltimore and many others. The first film to be distributed through the network was Artisan Entertainment's STANDING IN THE SHADOWS OF MOTOWN. MOTOWN had its digital debut at the historical Apollo Theater in New York City . Following MOTOWN, Digital Cinema Solutions electronically distributed over a virtual private network close to 100 films until it was sold in 2005.

The first DCI-compliant DCP to be delivered Universal Pictures used their film *Serenity* as the first DCI-compliant DCP to be delivered shown to an audience at a remote theater, although it was not distributed this way to the public. *Inside Man* was their first DCP cinema release, and was transmitted to 20 theatres in the United States along with two trailers.

In April 2005, DG2L Technologies announced that it had been awarded the multi-million dollar contract for the world's largest satellite based MPEG4 digital cinema deployment to be done in India, which encompassed 2000 theaters for UFO (United Film Organizers), a subsidiary of the Valuable Media Group. In March 2006, United Film Organizers Moviez (UFO Moviez), had reached a significant milestone—surpassing 30,000 shows using the DG2L Cinema System platform. This figure increased to 100,000 shows in August 2006. In September 2006, UFO Moviez acquired 51% stake in DG2L Technologies in a deal estimated at around $50 million.

Stereo 3-D images

In late 2005, interest in digital 3-D stereoscopic projection has led to a new willingness on the part of theaters to co-operate in installing a limited number of 2K stereo installations to show Disney's *Chicken Little* in 3-D film. Six more digital 3-D movies were released in 2006 and 2007 (including Beowulf, *Monster House* and *Meet the Robinsons*). The technology combines a single digital projector fitted with either a polarizing filter (for use with polarized glasses and silver screens), a filter wheel or an emitter for LCD glasses. RealD uses a "ZScreen" for polarisation and MasterImage uses a filter wheel that changes the polarity of projector's light output several times per second to alternate quickly the left-and-right-eye views. Another system that uses a filter wheel is Dolby 3D. The wheel changes the wavelengths of the colours being displayed, and tinted glasses filter these changes so the incorrect wavelength cannot enter the wrong eye. XpanD makes use of an external emitter that sends a signal to the 3D glasses to block out the wrong image from the wrong eye.

List of digital cinema companies

- Barco — digital projector manufacturer
- Christie — digital projector manufacturer
- Deluxe Digital Studios — distributor and theater system integrator
- Dolby Laboratories — theater system integrator
- IMAX — digital projector manufacturer
- Kodak — theater system integrator
- NEC — digital projector manufacturer
- RealD Cinema — 3D cinema display technology
- RED Digital Cinema Camera Company — digital cinema camera manufacturer
- Sony — manufacturer of 4K digital projector and digital cinema servers and theater system integrator
- Technicolor — distributor and theater system integrator
- Texas Instruments — developers of DLP projector technology
- XDC — theater system integrator & digital server manufacturer

Chapter- 3

3-D Film

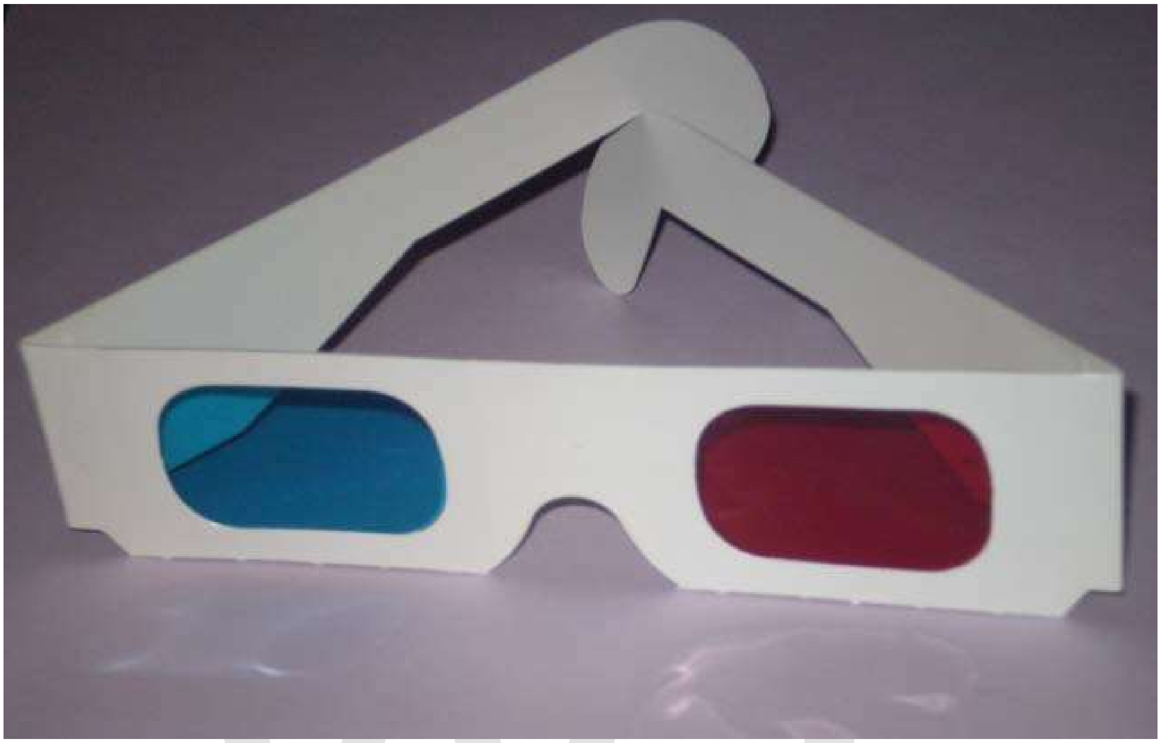
A **3-D** (**three-dimensional**) **film** or **S3D** (**stereoscopic 3D**) **film** is a motion picture that enhances the illusion of depth perception. Derived from stereoscopic photography, a special motion picture camera system is used to record the images as seen from two perspectives (or computer-generated imagery generates the two perspectives), and special projection hardware and/or eyewear are used to provide the illusion of depth when viewing the film. 3-D films are not limited to feature film theatrical releases; television broadcasts and direct-to-video films have also incorporated similar methods, primarily for marketing purposes.

3-D films have existed in some form since the 1950s, but had been largely relegated to a niche in the motion picture industry because of the costly hardware and processes required to produce and display a 3-D film, and the lack of a standardized format for all segments of the entertainment business. Nonetheless, 3-D films were prominently featured in the 1950s in American cinema, and later experienced a worldwide resurgence in the 1980s and '90s driven by IMAX high-end theaters and Disney themed-venues. 3-D films became more and more successful throughout the 2000s, culminating in the unprecedented success of 3-D presentations of *Avatar* in December 2009 and January 2010.

Techniques

Stereoscopic motion pictures can be produced through a variety of different methods. Over the years the popularity of systems being widely employed in movie theaters has waxed and waned. Though anaglyph was sometimes used prior to 1948, during the early "Golden Era" of 3-D cinematography of the 1950s the polarization system was used for every single feature length movie in the United states, and all but one short film. In the 21st century, polarization 3-D systems have continued to dominate the scene, though during the 60s and 70s some classic films which were converted to anaglyph for theaters not equipped for polarization, and were even shown in 3-D on TV. In the years following the mid 80s, some movies were made with short segments in anaglyph 3D. The following are some of the technical details and methodologies employed in some of the more notable 3-D movie systems that have been developed.

Anaglyph



The archetypical 3-D glasses, with modern red and cyan color filters, similar to the red/green and red/blue lenses used to view early anaglyph films.

Anaglyph images were the earliest method of presenting theatrical 3-D, and the one most commonly associated with stereoscopy by the public at large, mostly because of non theatrical 3D media such as comic books and 3D TV broadcasts, where polarization is not practical. They were made popular because of the ease of their production and exhibition. Though the earliest theatrical presentations were done with this system, most 3D movies from the 50s and 80s were originally shown polarized.

In an anaglyph, the two images are superimposed in an additive light setting through two filters, one red and one cyan. In a subtractive light setting, the two images are printed in the same complementary colors on white paper. Glasses with colored filters in each eye separate the appropriate images by canceling the filter color out and rendering the complementary color black.

Anaglyph images are much easier to view than either parallel sighting or crossed eye stereograms, although the latter types offer bright and accurate color rendering, particularly in the red component, which is muted, or desaturated with even the best color anaglyphs. A compensating technique, commonly known as Anachrome, uses a slightly more transparent cyan filter in the patented glasses associated with the technique. Process reconfigures the typical anaglyph image to have less parallax.

An alternative to the usual red and cyan filter system of anaglyph is **ColorCode 3-D**, a patented anaglyph system which was invented in order to present an anaglyph image in conjunction with the NTSC television standard, in which the red channel is often compromised. ColorCode uses the complementary colors of yellow and dark blue on-screen, and the colors of the glasses' lenses are amber and dark blue.

The *anaglyph 3-D system* was the earliest system used in theatrical presentations and requires less specialized hardware.

The *polarization 3-D system* has been the standard for theatrical presentations since it was used for *Bwana Devil* in 1952, though early Imax presentations were done using the eclipse system and in the 60s and 70s classic 3D movies were sometimes converted to anaglyph for special presentations. The polarization system has better color fidelity and less ghosting than the anaglyph system.

In the post-'50s era, anaglyph has been used instead of polarization in feature presentations where only part of the movie is in 3D such as in the 3D segment of *Freddy's Dead: The Final Nightmare* and the 3D segments of *Spy Kids 3D*.

Anaglyph is also used in printed materials and in 3D TV broadcasts where polarization is not practical. 3D polarized TVs and other displays only became available from several manufacturers in 2008, these generate polarization on the receiving end, polarized light is not broadcast.

Polarization systems

cardboard 3D linear polarized glasses from the 80s similar to those used in the 50s. Though some were plain white, they often had the name of the theatre and/or graphics from the movie

To present a stereoscopic motion picture, two images are projected superimposed onto the same screen through different polarizing filters. The viewer wears low-cost eyeglasses which also contain a pair of polarizing filters oriented differently (clockwise/counterclockwise with circular polarization or at 90 degree angles, usually 45 and 135 degrees, with linear polarization). As each filter passes only that light which is similarly polarized and blocks the light polarized differently, each eye sees a different image. This is used to produce a three-dimensional effect by projecting the same scene into both eyes, but depicted from slightly different perspectives. Since no head tracking is involved, the entire audience can view the stereoscopic images at the same time.

Resembling sunglasses, RealD circular polarized glasses are now the standard for theatrical releases and theme park attractions.

In the case of RealD a circularly polarizing liquid crystal filter which can switch polarity 144 times per second is placed in front of the projector lens. Only one projector is needed, as the left and right eye images are displayed alternately. Sony features a new system called RealD XLS, which shows both circular polarized images simultaneously: a single 4K projector (4096×2160 resolution) displays both 2K images (2048×858 resolution) on top of each other at the same time, a special lens attachment polarizes and projects the images.

Thomson Technicolor has produced a system using a split lens which allows traditional 35mm projectors to be adapted to project in 3D using over/under 35mm film. This is a very cost-effective way to convert a screen as all that is needed is the lens and metallic (silver) screen rather than converting entirely to digital. A metallic screen is necessary for these systems as reflection from non metallic surfaces destroys the polarization of the light.

Polarized stereoscopic pictures have been around since 1936, when Edwin H. Land first applied it to motion pictures. The so called "3-D movie craze" in the years 1952 through 1955 was almost entirely offered in theaters using linear polarizing projection and glasses. Only a minute amount of the total 3D films shown in the period used the anaglyph color filter method. Linear polarization was likewise used with consumer level stereo projectors. Polarization was also used during the 3D revival of the 80s.

In the 2000s, computer animation, competition from DVDs and other media, digital projection, and the use of sophisticated IMAX 70mm film projectors, have created an opportunity for a new wave of polarized 3D films.

Eclipse method

With the eclipse method, a mechanical shutter blocks light from each appropriate eye when the converse eye's image is projected on the screen. The projector alternates between left and right images, and opens and closes the shutters in the glasses or viewer in synchronization with the images on the screen. This was the basis of the Teleview system which was used briefly in 1922.

A pair of LCD shutter glasses used to view XpanD 3D films

A variation on the eclipse method is used in LCD shutter glasses. Glasses containing liquid crystal that will let light through in synchronization with the images on the computer display or TV, using the concept of alternate-frame sequencing. This is the method used by nVidia, XpanD 3D, and earlier IMAX systems. A drawback of this method is the need for each person viewing to wear expensive, electronic glasses that must be synchronized with the display system using a wireless signal or attached wire. The shutterglasses are heavier than most polarized glasses though lighter models are no heavier than some sunglasses or deluxe polarized glasses.

Interference filter technology

Dolby 3D uses specific wavelengths of red, green, and blue for the right eye, and different wavelengths of red, green, and blue for the left eye. Eyeglasses which filter out the very specific wavelengths allow the wearer to see a 3D image. This technology eliminates the expensive silver screens required for polarized systems such as RealD, which is the most common 3D display system in theaters. It does, however, require much more expensive glasses than the polarized systems. It is also known as **wavelength multiplex visualization**.

Pulfrich

The Pulfrich effect is based on the phenomenon of the human eye processing images more slowly when there is less light, as when looking through a dark lens.

Imagine a camera which starts at position X and moves right to position Y as shown by the arrow. If a viewer watches this segment with a dark lens over the left eye, then when the right eye sees the image recorded when the camera is at Y, the left eye will be a few milliseconds behind and will still be seeing the image recorded at X, thus creating the necessary parallax to generate right and left eye views and 3D perception, much the same as when still pictures are generated by shifting a single camera. The intensity of this effect will depend on how fast the camera is moving relative to the distance to the objects; greater speed creates greater parallax. A similar effect can be achieved by using a stationary camera and continuously rotating an otherwise stationary object. If the movement stops, the eye looking through the dark lens (which could be either eye depending on the direction the camera is moving) will "catch up" and the effect will disappear. One advantage of this system is that people not wearing the glasses will see a perfectly normal picture.

Of course, incidental movement of objects will create spurious artifacts, and these incidental effects will be seen as artificial depth not related to actual depth in the scene. Unfortunately, many of the applications of pulfrich involve deliberately causing just this sort of effect and this has given the technique a bad reputation. When the only movement is lateral movement of the camera then the effect is as real as any other form of stereoscopy, but this seldom happens except in highly contrived situations.

Though pulfrich has been used often on TV and in computer games, it is rarely if ever used in theatrical presentations.

Spectral separation

ChromaDepth uses a holographic film in the glasses that creates an effect like a dispersive prism. This causes redder objects to be perceived as near and bluer objects as farther away.

Lenticular or barrier screens

In this method, glasses are not necessary to see the stereoscopic image.

Both images are projected onto a high-gain, corrugated screen which reflects light at acute angles. In order to see the stereoscopic image, the viewer must sit within a very narrow angle that is nearly perpendicular to the screen, limiting the size of the audience. Lenticular was used for theatrical presentation of numerous shorts in Russia from 1940–1948 and in 1954 for the feature length films *Crystal*, *Machine 22-12* and *The Pencil on Ice*.

Though its use in theatrical presentations has been rather limited, lenticular has been widely used for a variety of novelty items and has even been used in amateur 3D photography.

New systems without glasses

There is increasing emergence of new 3-D viewing systems which do not require the use of special viewing glasses. These systems are referred to as Autostereoscopic displays. They were initially developed by Sharp. The first Autostereoscopic LCD displays first appeared on the Sharp Actius RD3D notebook and the first LCD monitor was shipped by Sharp in 2004 for the professional market. Both have since been discontinued. The first Autostereoscopic mobile phone was launched by Hitachi in 2009 in Japan and in 2010 China mobile is to launch its version. Manufacturing trials are being run for TV. For the gaming market the first probable commercial application will be handheld gaming devices, such as the Nintendo 3DS. These systems do not yet appear to be applicable to theatrical presentations.

History

Early patents and tests

The stereoscopic era of motion pictures began in the late 1890s when British film pioneer William Friese-Greene filed a patent for a 3-D movie process. In his patent, two films were projected side by side on screen. The viewer looked through a stereoscope to converge the two images. Because of the obtrusive mechanics behind this method, theatrical use was not practical. Frederick Eugene Ives patented his stereo camera rig in 1900. The camera had two lenses coupled together 1 3/4 inches apart.

On June 10, 1915, Edwin S. Porter and William E. Waddell presented tests to an audience at the Astor Theater in New York City. In red-green anaglyph, the audience was presented three reels of tests, which included rural scenes, test shots of Marie Doro, a segment of John Mason playing a number of passages from *Jim the Penman* (a film released by Famous Players-Lasky that year, but not in 3-D), Oriental dancers, and a reel of footage of Niagara Falls. However, according to Adolph Zukor in his 1953 autobiography *The Public Is Never Wrong: My 50 Years in the Motion Picture Industry*, nothing was produced in this process after these tests.

Early systems of stereoscopic filmmaking (pre-1952)

The earliest confirmed 3-D film shown to a paying audience was *The Power of Love*, which premiered at the Ambassador Hotel Theater in Los Angeles on September 27, 1922. The camera rig was a product of the film's producer, Harry K. Fairall, and cinematographer Robert F. Elder. It was projected dual-strip in the red/green anaglyph format, making it both the earliest known film that utilized dual strip projection and the earliest known film in which anaglyph glasses were used. Whether Fairall used colored filters on the projection ports or whether he used tinted prints is unknown. After a preview for exhibitors and press in New York City, the film dropped out of sight, apparently not booked by exhibitors, and is now considered lost.

Early in December 1922, William Van Doren Kelley, inventor of the Prizma color system, cashed in on the growing interest in 3-D films started by Fairall's demonstration and shot footage with a camera system of his own design. Kelley then struck a deal with Samuel "Roxy" Rothafel to premiere the first in his series of "Plasticon" shorts entitled *Movies of the Future* at the Rivoli Theater in New York City .

Kelley, who was an early producer of color films, used Prizma to print his anaglyph films. In early 1923, he shopped around a second Plasticon entitled *Through the Trees – Washington, D.C.*, shot by William T. Crespinel, which consisted of stereoscopic views of Washington, D.C., but found no buyers.

A detail from an article about the Teleview system, created by Hammond and Cassidy. Only one feature was ever produced with the system.

Also in December 1922, Laurens Hammond (later inventor of the Hammond organ) and William F. Cassidy unveiled their Teleview system. Teleview was the earliest alternate-frame sequencing form of film projection. Through the use of two interlocked projectors, alternating left/right frames were projected one after another in rapid succession. Synchronized viewers attached to the arm-rests of the seats in the theater open and closed at the same time, and took advantage of the viewer's persistence of vision, thereby creating a true stereoscopic image. The only theater known to have installed this system was the Selwyn Theater in New York. Only one show was ever produced for the system, a groups of shorts and the only Teleview feature *The Man From M.A.R.S.* (later re-released as *Radio-Mania*) on December 27, 1922 in New York City.

In 1922, Frederic Eugene Ives and Jacob Leventhal began releasing their first stereoscopic shorts made over a three-year period. The first film entitled, *Plastigrams*, which was distributed nationally by Educational Pictures in the red/blue anaglyph format. Ives and Leventhal then went on to produce the following stereoscopic shorts in the "Stereoscopiks Series" for Pathé Films in 1925: *Zowie* (April 10), *Luna-cy!* (May 18), *The Run-Away Taxi* (December 17) and *Ouch* (December 17). On 22 September 1924, *Luna-cy!* was re-released in the DeForest Phonofilm sound-on-film system.

The late 1920s to early 1930s saw little to no interest in stereoscopic pictures, largely due to the Great Depression. In Paris, Louis Lumiere shot footage with his stereoscopic camera in September 1933. The following year, in March 1934, he premiered his remake of his 1895 film *L'Arrivée du Train*, this time in anaglyphic 3-D, at a meeting of the French Academy of Science.

In 1936, Leventhal and John Norling were hired based on their test footage to film MGM's *Audioscopiks* series. The prints were by Technicolor in the red/green anaglyph format, and were narrated by Pete Smith. The first film, *Audioscopiks*, premiered January 11, 1936 and *The New Audioscopiks* premiered January 15, 1938. *Audioscopiks* was nominated for the Academy Award in the category Best Short Subject, Novelty in 1936.

With the success of the two Audioscopiks films, MGM produced one more short in anaglyph 3-D, another Pete Smith Specialty called *Third Dimensional Murder* (1941). Unlike its predecessors, this short was shot with a studio-built camera rig. Prints were by Technicolor in red/blue anaglyph. The short is notable for being one of the few live-action appearances of the Frankenstein Monster as conceived by Jack Pierce for Universal Studios outside of their company.

While many of these films were printed by color systems, none of them was actually in color, and the use of the color printing was only to achieve an anaglyph effect.

Introduction of Polaroid

While attending Harvard University, Edwin H. Land conceived the idea of reducing glare by polarizing light. He took a leave of absence from Harvard to set up a lab and by 1929 had invented and patented a polarizing sheet. In 1932, he introduced **Polaroid J Sheet** as a commercial product. While his original intention was to create a filter for reducing glare from car headlights, Land did not underestimate the utility of his newly dubbed Polaroid filters in stereoscopic presentations.

In January 1936, Land gave the first demonstration of Polaroid filters in conjunction with 3-D photography at the Waldorf-Astoria Hotel. The reaction was enthusiastic, and he followed it up with an installation at the New York Museum of Science. It is unknown what film was run for audiences with this installation.

Using Polaroid filters meant an entirely new form of projection, however. Two prints, each carrying either the right or left eye, had to be synced up in projection using an external selsyn motor. Furthermore, polarized light would not register on a matte white screen, and only a silver screen or screen made of other reflective material would correctly reflect the separate images.

Later that year, the feature, *Nozze Vagabonde* appeared in Italy, followed in Germany by *Zum Greifen Nah* (*You Can Nearly Touch It*), and again in 1939 with Germany's *Sechs Mädel Rollen Ins Wochenend* (*Six Girls Drive Into the Weekend*). The Italian film was made with the Gualtierotti camera; the two German productions with the Zeiss camera and the Vierling shooting system. All of these films were the first exhibited using Polaroid filters. The Zeiss Company in Germany manufactured glasses on a commercial basis commencing in 1936; they were also independently made around the same time in Germany by E. Käsemann and by J. Mahler.

In 1939, John Norling shot *In Tune With Tomorrow*, the first commercial 3-D film using Polaroid in the US. This short premiered at the 1939 New York World's Fair and was created specifically for the Chrysler Motor Pavilion. In it, a full 1939 Chrysler Plymouth is magically put together, set to music. Originally in black and white, the film was so popular that it was re-shot in color for the following year at the fair, under the title *New Dimensions*. In 1953, it was reissued by RKO as *Motor Rhythm*.

Another early short that utilized the Polaroid 3-D process was 1940's *Magic Movies: Thrills For You* produced by the Pennsylvania Railroad Co. for the Golden Gate International Exposition. Produced by John Norling, it was actually shot for him by Jacob Leventhal using his own rig. It consisted of shots of various views that could be seen on Pennsylvania Railroad's trains.

The 1940s was further hindered by World War II, and stereoscopic photography once again went on the back-burner in most producers' minds.

The "golden era" (1952–1955)

What aficionados consider the "golden era" of 3-D began in 1952 with the release of the first color stereoscopic feature, *Bwana Devil*, produced, written and directed by Arch Oboler. The film was shot in *Natural Vision*, a process that was co-created and controlled by M. L. Gunzberg. Gunzberg, who built the rig with his brother, Julian, and two other associates, shopped it without success to various studios before Oboler used it for this feature, which went into production with the title, *The Lions of Gulu*. The film starred Robert Stack, Barbara Britton and Nigel Bruce.

As with practically all of the features made during this boom, *Bwana Devil* was projected dual-strip, with Polaroid filters. During the 1950s, the familiar disposable anaglyph glasses made of cardboard were mainly used for comic books, two shorts by exploitation specialist Dan Sonney, and three shorts produced by Lippert Productions. However, even the Lippert shorts were available in the dual-strip format alternatively.

Because the features utilized two projectors, a capacity limit of film being loaded onto each projector (about 6,000 feet (1,800 m), or an hour's worth of film) meant that an intermission was necessary for every feature-length film. Quite often, intermission points were written into the script at a major plot point.

During Christmas of 1952, producer Sol Lesser quickly premiered the dual-strip showcase called *Stereo Techniques* in Chicago. Lesser acquired the rights to five dual-strip shorts. Two of them, *Now is the Time (to Put On Your Glasses)* and *Around is Around*, were directed by Norman McLaren in 1951 for the National Film Board of Canada. The other three films were produced in Britain for Festival of Britain in 1951 by Raymond Spottiswoode. These were *A Solid Explanation*, *Royal River*, and *The Black Swan*.

James Mage was also an early pioneer in the 3-D craze. Using his 16 mm 3-D Bolex system, he premiered his *Triorama* program on February 10, 1953 with his four shorts: *Sunday In Stereo*, *Indian Summer*, *American Life*, and *This is Bolex Stereo*. This show is considered lost.

Another early 3-D film during the boom was the Lippert Productions short, *A Day in the Country*, narrated by Joe Besser and composed mostly of test footage. Unlike all of the other Lippert shorts, which were available in both dual-strip and anaglyph, this production was released in anaglyph only.

April 1953 saw two groundbreaking features in 3-D: Columbia's *Man in the Dark* and Warner Bros. *House of Wax*, the first 3-D feature with stereophonic sound. *House of Wax*, outside of Cinerama, was the first time many American audiences heard recorded stereophonic sound. It was also the film that typecast Vincent Price as a horror star as well as the "King of 3-D" after he became the actor to star in the most 3-D features (the others were *The Mad Magician*, *Dangerous Mission*, and *Son of Sinbad*). The success of these two films proved that major studios now had a method of getting moviegoers back into theaters and away from television sets, which were causing a steady decline in attendance.

The Walt Disney Studios waded into 3-D with its May 28, 1953 release of *Melody*, which accompanied the first 3-D western, Columbia's *Fort Ti* at its Los Angeles opening. It was later shown at Disneyland's Fantasyland Theater in 1957 as part of a program with Disney's other short *Working for Peanuts*, entitled, *3-D Jamboree*. The show was hosted by the Mousketeers and was in color.

Universal-International released their first 3-D feature on May 27, 1953, *It Came from Outer Space*, with stereophonic sound. Following that was Paramount's first feature, *Sangaree* with Fernando Lamas and Arlene Dahl.

Columbia released several 3-D westerns produced by Sam Katzman and directed by William Castle. Castle would later specialize in various technical in-theater gimmicks for such Columbia and Allied Artists features as *13 Ghosts*, *House on Haunted Hill*, and *The Tingler*. Columbia also produced the only slapstick comedies conceived for 3-D. The Three Stooges starred in *Spooks* and *Pardon My Backfire*; dialect comic Harry Mimmo starred in *Down the Hatch*. Producer Jules White was optimistic about the possibilities of 3-D as applied to slapstick (with pies and other projectiles aimed at the audience), but only two of his stereoscopic shorts were shown in 3-D. *Down the Hatch* was released as a conventional, "flat" motion picture. (Columbia has since printed *Down the Hatch* in 3-D for film festivals.)

John Ireland, Joanne Dru and Macdonald Carey starred in the Jack Broder color production *Hannah Lee*, which premiered June 19, 1953. The film was directed by Ireland, who sued Broder for his salary. Broder counter-sued, claiming that Ireland went over production costs with the film.

Another famous entry in the golden era of 3-D was the 3 Dimensional Pictures production of *Robot Monster*. The film was allegedly scribed in an hour by screenwriter Wyott Ordung and filmed in a period of two weeks on a shoestring budget. Despite these shortcomings and the fact that the crew had no previous experience with the newly-built camera rig, luck was on the cinematographer's side, as many find the 3-D photography in the film is well shot and aligned. *Robot Monster* also has a notable score by then up-and-coming composer Elmer Bernstein. The film was released June 24, 1953 and went out with the short *Stardust in Your Eyes*, which starred nightclub comedian, Slick Slavin.

20th Century Fox produced their only 3-D feature, *Inferno*, starring Rhonda Fleming. Fleming, who also starred in *Those Redheads from Seattle*, and *Jivaro*, shares the spot for being the actress to appear in the most 3-D features with Patricia Medina, who starred in *Sangaree*, *Phantom of the Rue Morgue* and *Drums of Tahiti*. Darryl F. Zanuck expressed little interest in stereoscopic systems, and at that point was preparing to premiere the new widescreen film system, CinemaScope.

The first decline in the theatrical 3-D craze started in August and September 1953. The factors causing this decline were:

- Two prints had to be projected simultaneously.
- The prints had to remain exactly alike after repair, or synchronization would be lost.
- It sometimes required two projectionists to keep sync working properly.
- When either prints or shutters became out of sync, the picture became virtually unwatchable and accounted for headaches and eyestrain.
- The necessary silver projection screen was very directional and caused sideline seating to be unusable with both 3-D and regular films, due to the angular darkening of these screens. Later films that opened in wider-seated venues often premiered flat for that reason (such as *Kiss Me Kate* at the Radio City Music Hall).
- The few cartoons made in 3D had a "cardboard cutout" effect, where flat objects appeared on different planes.

Because projection booth operators were at many times careless, even at preview screenings of 3-D films, trade and newspaper critics claimed that certain films were "hard on the eyes."

Sol Lesser attempted to follow up *Stereo Techniques* with a new showcase, this time five shorts that he himself produced. The project was to be called *The 3-D Follies* and was to be distributed by RKO. Unfortunately, because of financial difficulties and the growing disinterest in 3-D, Lesser canceled the project during the summer of 1953, making it the first 3-D film to be aborted in production. Two of the three shorts were shot: *Carmenesque*, a burlesque number starring exotic dancer Lili St. Cyr. and *Fun in the Sun*, a sports short directed by famed set designer/director William Cameron Menzies, who also directed the 3-D feature *The Maze* for Allied Artists.

Although it was more expensive to install, the major competing realism process was anamorphic, first utilized by Fox with Cinemascope and its September premiere in *The Robe*. Anamorphic features needed only a single print, so synchronization was not an issue. Cinerama was also a competitor from the start and had better quality control than 3-D because it was owned by one company that focused on quality control. However, most of the 3-D features past the summer of 1953 were released in the flat widescreen formats ranging from 1.66:1 to 1.85:1. In early studio advertisements and articles about widescreen and 3-D formats, widescreen systems were referred to as "3-D", causing some confusion among scholars.

There was no single instance of combining Cinemascope with 3-D until 1960, with a film called *September Storm*, and even then, that was a blow-up from a non-anamorphic negative. *September Storm* also went out with the last dual-strip short, *Space Attack*, which was actually shot in 1954 under the title *The Adventures of Sam Space*.

In December 1953, 3-D made a comeback with the release of several important 3-D films, including MGM's musical *Kiss Me, Kate*. *Kate* was the hill over which 3-D had to pass to survive. MGM tested it in six theaters: three in 3-D and three flat. According to trade ads of the time, the 3-D version was so well-received that the film quickly went into a wide stereoscopic release. However, most publications, including Kenneth Macgowan's classic film reference book *Behind the Screen*, state that the film did much better as a "regular" release. The film, adapted from the popular Cole Porter Broadway musical, starred the MGM songbird team of Howard Keel and Kathryn Grayson as the leads, supported by Ann Miller, Keenan Wynn, Bobby Van, James Whitmore, Kurt Kasznar and Tommy Rall. The film also prominently promoted its use of stereophonic sound.

Several other features that helped put 3-D back on the map that month were the John Wayne feature *Hondo* (distributed by Warner Bros.), Columbia's *Miss Sadie Thompson* with Rita Hayworth, and Paramount's *Money From Home* with Dean Martin and Jerry Lewis. Paramount also released the cartoon shorts *Boo Moon* with Casper, the Friendly Ghost and *Popeye, Ace of Space* with Popeye the Sailor. Paramount Pictures released a 3-D Korean War film *Cease Fire* filmed on actual Korean locations in 1953.

Top Banana, based on the popular stage musical with Phil Silvers, was brought to the screen with the original cast. Although it was merely a filmed stage production, the idea was that every audience member would feel they would have the best seat in the house through color photography and 3-D. Although the film was shot and edited in 3-D, United Artists, the distributor, felt the production was uneconomical in stereoscopic form and released the film flat on January 27, 1954. It remains one of two "Golden era" 3- D features, along with another United Artists feature, *Southwest Passage* (with John Ireland and Joanne Dru), that are currently considered lost (although flat versions survive).

A string of successful 3-D movies followed the second wave. Some highlights are:

- *The French Line*, starring Jane Russell and Gilbert Roland, a Howard Hughes/RKO production. The film became notorious for being released without an MPAA seal of approval, after several suggestive lyrics were included, as well as one of Ms. Russell's particularly revealing costumes. Playing up her sex appeal, one tagline for the film was, "It'll knock *both* of your eyes out!" The film was later cut and approved by the MPAA for a general flat release, despite having a wide and profitable 3-D release.

- *Taza, Son of Cochise*, a sequel to 1950's *Broken Arrow*, which starred Rock Hudson in the title role, Barbara Rush as the love interest, and Rex Reason (billed as Bart Roberts) as his renegade brother, released through Universal-International. It was directed by the great stylist Douglas Sirk, and his striking visual sense made the film a huge success when it was "re-premiered" in 2006 at the Second 3-D Expo in Hollywood.
- Two ape films: *Phantom of the Rue Morgue*, featuring Karl Malden and Patricia Medina, and produced by Warner Bros. and based on Edgar Allan Poe's "The Murders in the Rue Morgue", and *Gorilla At Large*, a Panoramic Production starring Cameron Mitchell, distributed through Fox.
- *Creature from the Black Lagoon*, starring Richard Carlson and Julie Adams, directed by Jack Arnold. Arguably the most famous 3-D movie, and the only 3-D feature that spawned a sequel, *Revenge of the Creature* in 3-D (followed by another sequel, *The Creature Walks Among Us*, shot flat).
- *Cat-Women of the Moon*, an Astor Picture starring Victor Jory and Marie Windsor. Elmer Bernstein composed the score.
- *Dial M for Murder*, directed by Alfred Hitchcock and starring Ray Milland, Robert Cummings, and Grace Kelly, is considered by aficionados of 3-D to be one of the best examples of the process. Although available in 3-D in 1954, there are no known playdates in 3-D, since Warner Bros. had just instated a simultaneous 3-D/2-D release policy. The film's screening in 3-D in February 1980 at the York Theater in San Francisco did so well that Warner Bros. re-released the film in 3-D in February 1982.
- *Gog*, an Ivan Tors production, dealing with realistic science fiction. The second film in Tors' "Office of Scientific Investigation" trilogy of film, which included, *The Magnetic Monster* and *Riders to the Stars*.
- *The Diamond Wizard*, the only stereoscopic feature shot in Britain, released flat in both the UK and US. It starred and was directed by Dennis O'Keefe.
- Irwin Allen's *Dangerous Mission* released by RKO in 1954 featuring Allen's trademarks of an all star cast facing a disaster (a forest fire).
- *Son of Sinbad*, another RKO/Howard Hughes production, starring Dale Robertson, Lili St. Cyr, and Vincent Price. The film was shelved after Hughes ran into difficulty with *The French Line*, and wasn't released until 1955, at which time it went out flat, converted to the SuperScope process.

3-D's final decline was in the late spring of 1954, for the same reasons as the previous lull, as well as the further success of widescreen formats with theater operators. Even though Polaroid had created a well-designed "Tell-Tale Filter Kit" for the purpose of recognizing and adjusting out of sync and phase 3-D, exhibitors still felt uncomfortable with the system and turned their focus instead to processes such as CinemaScope. The last 3-D feature to be released in that format during the "Golden era" was *Revenge of the Creature*, on February 23, 1955. Ironically, the film had a wide release in 3-D and was well received at the box office.

Revival (1960–1984) in single strip format

Stereoscopic films largely remained dormant for the first part of the 1960s, with those that were released usually being anaglyph exploitation films. One film of notoriety was the Beaver-Champion/Warner Bros. production, *The Mask* (1961). The film was shot in 2-D, but to enhance the bizarre qualities of the dream-world that is induced when the main character puts on a cursed tribal mask, the film went to anaglyph 3-D. These scenes were printed by Technicolor on their first run in red/green anaglyph.

Although 3-D films appeared sparsely during the early 1960s, the true second wave of 3-D cinema was set into motion by Arch Oboler, the same producer who started the craze of the 1950s. Using a new technology called *Space-Vision 3D*, stereoscopic films were printed with two images, one above the other, in a single academy ratio frame, on a single strip, and needed only one projector fitted with a special lens. This so-called "over and under" technique eliminated the need for dual projector set-ups, and produced widescreen, but darker, less vivid, polarized 3-D images. Unlike earlier dual system, it could stay in perfect sync, unless improperly spliced in repair.

Arch Oboler once again had the vision for the system that no one else would touch, and put it to use on his film entitled *The Bubble*, which starred Michael Cole, Deborah Walley, and Johnny Desmond. As with *Bwana Devil*, the critics panned *The Bubble*, but audiences flocked to see it, and it became financially sound enough to promote the use of the system to other studios, particularly independents, who did not have the money for expensive dual-strip prints of their productions.

In 1970, Stereovision, a new entity founded by director/inventor Allan Silliphant and optical designer Chris Condon, developed a different 35 mm single-strip format, which printed two images squeezed side-by-side and used an anamorphic lens to widen the pictures through polaroid filters. Louis K. Sher (Sherpix) and Stereovision released the softcore sex comedy *The Stewardesses* (self-rated X, but later re-rated R by the MPAA). The film cost $100,000 USD to produce, and ran for months in several markets. eventually earning $27 million in North America, alone ($140 million in constant-2010 dollars) in fewer than 800 theaters, becoming the most profitable 3-Dimensional film to date, and in purely relative terms, one of the most profitable films ever. It was later released in 70 mm 3-D. Some 36 films worldwide were made with Stereovision over 25 years, using either a widescreen (above-below), anamorphic (side by side) or 70 mm 3-D formats. In 2009 *The Stewardesses* was remastered by Chris Condon and director Ed Meyer, releasing it in XpanD 3D, RealD Cinema and Dolby 3D.

The quality of the 1970s 3-D films was not much more inventive, as many were either softcore and even hardcore adult films, horror films, or a combination of both. Paul Morrisey's *Flesh For Frankenstein* (aka *Andy Warhol's Frankenstein*) was a superlative example of such a combination.

Between 1981 and 1983 there was a new 3D craze started by the spaghetti western *Comin' at Ya!*. When *Parasite* was released it was billed as the first horror film to come out in 3D in over 20 years. Horror movies and reissues of 1950s 3D classics (such as Hitchcock's *Dial ´M´ for Murder*) dominated the 3D releases that followed. The second sequel in the Friday the 13th series, *Friday the 13th Part III*, was released very successfully. Apparently saying "part 3 in 3D" was considered too cumbersome so it was shortened in the titles of *Jaws 3-D* and *Amityville 3-D*, which emphasized off the screen effects to the point of being annoying at times, especially when flashlights were shone into the eyes of the audience.

The science fiction film *Spacehunter: Adventures in the Forbidden Zone* was the most expensive 3D movie made up to that point with production costs about the same as *Star Wars* but not nearly the same box office success, causing the craze to fade quickly through spring 1983. Other sci-fi/fantasy films were released as well including *Metalstorm: The Destruction of Jared-Syn* and *Treasure of the Four Crowns*, which was widely criticized for poor editing and plot holes, but did feature some truly spectacular closeups.

3D releases after the second craze included *The Man Who Wasn't There* (1983), *Silent Madness* and the 1985 animated film *Starchaser: The Legend of Orin*, whose plot seemed to borrow heavily from *Star Wars* .

Only *Comin' At Ya!*, *Parasite*, and *Friday the 13th Part III* have been officially released on VHS and/or DVD in 3-D in the United States (although *Amityville 3-D* has seen a 3-D DVD release in the United Kingdom). Most of the 80s 3D movies and some of the classic 50s movies such as *House of Wax* were released on the now defunct Video Disc (VHD) format in Japan as part of a system that used shutter glasses. Most of these have been unofficially transferred to DVD and are available on the grey market through sites such as eBay.

Rebirth of 3-D (1985–2003)

In the mid 1980s, IMAX began producing non-fiction films for its nascent 3-D business, starting with "We Are Born of Stars" (Roman Kroitor, 1985). A key point was that this production, as with all subsequent IMAX productions, emphasized mathematical correctness of the 3D rendition and thus largely eliminated the eye fatigue and pain that resulted from the approximate geometries of previous 3D incarnations. In addition, and in contrast to previous 35mm based 3D presentations, the very large field of view provided by IMAX allowed a much broader 3D "stage", arguably as important in 3D film as it is theatre.

In 1986, Disney Theme Parks and Universal Studios began to use 3D films to impress audiences in special venues, Captain Eo (Francis Ford Coppola, 1986) starring Michael Jackson, being a very notable example. In the same year, the National Film Board of Canada production *Transitions* (Colin Low), created for Expo 86 in Vancouver, was the first IMAX presentation using polarized glasses. "Echos of the Sun" (Roman Kroitor, 1990) was the first IMAX film to be presented using alternate-eye shutterglass technology, a development required because the dome screen precluded the use of polarized technology.

From 1990 onward, numerous films were produced by all three parties to satisfy the demands of their various high-profile special attractions and IMAX's expanding 3D network. Films of special note during this period include the extremely successful "Into The Deep" (Graeme Ferguson, 1995) and the first IMAX 3-D fiction film *Wings of Courage* (1996), by director Jean-Jacques Annaud, about the pilot Henri Guillaumet.

Other stereoscopic films produced in this period include:

- *The Last Buffalo* (Stephen Low, 1990)
- *Jim Henson's Muppet*Vision 3D* (Jim Henson, 1991)
- *Imagine* (John Weiley, 1993)
- *Honey, I Shrunk the Audience* (Daniel Rustuccio, 1994)
- *Into the Deep* (Graeme Ferguson, 1995)
- *Across the Sea of Time* (Stephen Low, 1995)
- *Wings of Courage* (Jean-Jacques Annaud, 1996)
- *L5, First City in Space* (Graeme Ferguson, 1996)
- *T2 3-D: Battle Across Time* (James Cameron, 1996)
- *Paint Misbehavin* (Roman Kroitor and Peter Stephenson, 1997)
- *IMAX Nutcracker* (1997)
- *The Hidden Dimension* (1997)
- *T-Rex: Back to the Cretaceous* (Brett Leonard, 1998)
- *Mark Twain's America* (Stephen Low, 1998)
- *Siegfried & Roy: The Magic Box* (Brett Leonard, 1999)
- *Galapagos* (Al Giddings and David Clark, 1999)
- *Encounter in the Third Dimension* (Ben Stassen, 1999)
- *Alien Adventure* (Ben Stassen, 1999)
- *Ultimate G's* (2000)
- *Cyberworld* (Hugh Murray, 2000)
- *Cirque du Soleil: Journey of Man* (Keith Melton, 2000)
- *Haunted Castle* (Ben Stassen, 2001)
- *Space Station 3D* (Toni Myers, 2002)
- *SOS Planet* (Ben Stassen, 2002)
- *Ocean Wonderland* (2003)
- *Falling in Love Again* (Munro Ferguson, 2003)
- *Misadventures in 3D* (Ben Stassen, 2003)

By 2004, 54% (133 theaters of 248) of the IMAX community was 3D-capable.

Shortly thereafter, higher quality computer animation, competition from DVDs and other media, digital projection, digital video capture, and the use of sophisticated IMAX 70mm film projectors, created an opportunity for another wave of 3D films.

3-D re-enters mainstream cinema (2003–present)

In 2003, *Ghosts of the Abyss* by James Cameron was released as the first full-length 3-D IMAX feature filmed with the Reality Camera System. This camera system used the latest HD video cameras, not film, and was built for Cameron by Vince Pace, to his specifications. The same camera system was used to film *Spy Kids 3-D: Game Over* (2003), *Aliens of the Deep* IMAX (2005), and *The Adventures of Sharkboy and Lavagirl in 3-D* (2005).

In 2004, Las Vegas Hilton released Star Trek: The Experience which included two films. One of the films, Borg Invasion 4-D (Ty Granoroli), was in 3D. In August of the same year, rap group Insane Clown Posse released their ninth studio album *Hell's Pit*. One of two versions of the album contained a DVD featuring a 3-D short film for the track "Bowling Balls", shot in high-definition video.

In November 2004, *The Polar Express* was released as IMAX's first full-length, animated 3-D feature. It was released in 3,584 theaters in 2D, and only 66 IMAX locations. The return from those few 3-D theaters was about 25% of the total. The 3-D version earned about 14 times as much per screen as the 2D version. This pattern continued and prompted a greatly intensified interest in 3-D and 3-D presentation of animated films.

In June 2005, the Mann's Chinese 6 theatre in Hollywood became the first commercial movie theatre to be equipped with the Digital 3D format. Both *Singin' in the Rain* and *The Polar Express* were tested in the Digital 3D format over the course of several months. In November 2005, Walt Disney Studio Entertainment released *Chicken Little* in digital 3-D format.

The Butler's in Love, a short film directed by Anders Laursen and starring Elizabeth Berkley and Thomas Jane, was released on June 23, 2008. The film was shot at the former Industrial Light & Magic studios using KernerFX's prototype Kernercam stereoscopic camera rig.

Ben Walters suggests that both filmmakers and film exhibitors regain interest in 3-D film. There are now more 3-D exhibition equipments, and more dramatic films being shot in 3-D format. One incentive is that the technology is more mature. Shooting in 3-D format is less limited, and the result is more stable. Another incentive is the fact that while 2-D ticket sales are in an overall state of decline, revenues from 3-D tickets continue to grow.

Through the entire history of 3D presentations, techniques to convert existing 2D images for 3D presentation have existed. Few have been effective or survived. The combination of digital and digitized source material with relatively cost-effective digital post-processing has spawned a new wave of conversion products. In June 2006, IMAX and Warner Bros. released *Superman Returns* including 20 minutes of 3-D images converted from the 2-D original digital footage. George Lucas has announced that he may re-release his *Star Wars* films in 3-D based on a conversion process from the company In-Three.

In late 2005, Steven Spielberg told the press he was involved in patenting a 3-D cinema system that does not need glasses, and which is based on plasma screens. A computer splits each film-frame, and then projects the two split images onto the screen at differing angles, to be picked up by tiny angled ridges on the screen.

Animated films *Open Season*, and *The Ant Bully*, were released in Analog 3D in 2006. *Monster House* and *The Nightmare Before Christmas* were released on XpanD 3D, RealD and Dolby 3D systems in 2006.

On May 19, 2007 *Scar3D* opened at the Cannes Film Market. It was the first US produced 3D full length feature film to be completed in Real D 3D. It has been the #1 film at the box office in several countries around the world, including Russia where it opened in 3D on 295 screens.

2008 3-D films included *Hannah Montana & Miley Cyrus: Best of Both Worlds Concert*, *Journey to the Center of the Earth*, and *Bolt*.

On January 16, 2009, Lionsgate released *My Bloody Valentine 3D*, the first horror film and first R-rated film to be projected in Real D 3D. It was released to 1,033 3D screens, the most ever for this format, and 1,501 regular screens. Another R-Rated film, *The Final Destination*, was released later that year (August 28) to even more screens. It was the first of its series to be released in HD 3-D.

On May 7, 2009 the British Film Institute commissioned a 3D film installation. The film *Radio Mania: An Abandoned Work* consists of two screens of stereoscopic 3D film with 3D Ambisonic sound. It stars Kevin Eldon and is by British artists Iain Forsyth and Jane Pollard.

The first 3-D Webisode series was *Horrorween* starting September 1, 2009.

> “ I think it's a misnomer to call it 3-D versus 2-D. The whole point of cinematic imagery is it's three-dimensional....95% of our depth cues come from occlusion, resolution, color and so forth, so the idea of calling a 2-D movie a '2-D movie' is a little misleading....When you watch through any of the conventional 3-D processes you're giving up three foot-lamberts. A massive difference,...[though] your eye compensates. ”
>
> — Director Christopher Nolan

Major 3-D films in 2009 included *Coraline*, *Monsters vs. Aliens*, *Up*, *X Games 3D: The Movie*, *The Final Destination*, and *Avatar*. *Avatar* has gone on to be one of the most expensive films of all time, with a budget at 237M; it is also the highest-grossing film of all time. The main presentation technologies were Real D 3D, Dolby 3D, XpanD 3D, MasterImage 3D, and IMAX 3D.

March and April 2010 saw three major 3-D releases clustered together, with *Alice in Wonderland* hitting US theaters on March 5, 2010, *How to Train Your Dragon* on March 26, 2010 and *Clash of the Titans* on April 2, 2010.

On May 13, 2010, China's first IMAX 3D film started shooting. The pre-production of the first 3-D French shot film Derrière les murs began in May 2010.

On October 1, 2010 *Scar3D* was the first-ever stereoscopic 3D Video-on-demand film released through major cable broadcasters for 3D televisions in the United States.

Released in the United States on May 21, 2010, *Shrek Forever After* by DreamWorks Animation (Paramount Pictures) used the Real D 3D system, also released in IMAX 3D.

Due to growing popularity of 3-D and an increase in 3-D screens, the latter half of 2010 will have an unprecedented amount of 3-D theatrical film releases, about three per month.

2011 will continue the 3D film releases with

Wide Release 3-D films in this era include:

2003

- *Spy Kids 3-D: Game Over* [Dimension Films] (Digital 3D)

2004

- *The Polar Express* [Warner Bros.] (IMAX 3D, 66 locations)

2005

- *The Adventures of Sharkboy and Lavagirl in 3-D* [Dimension, Columbia] (Digital 3D)
- *Chicken Little* [Disney] (Digital 3D, 84 locations)

2006

- *Open Season* [Columbia] (Analog 3D)
- *The Ant Bully* [Warner Bros.] (IMAX 3D)
- *Monster House* [Colombia] (Real D in 200+ Locations)
- *The Nightmare Before Christmas* (Re-Release) [Disney] (XPan 3d, Real D, Dolby 3D)

2007

- *Beowulf* [Paramount, Warner Bros.] (IMAX 3D, Real D, Dolby 3D)
- *Meet the Robinsons* [Disney] (Real D, 600+ locations)

2008

- *Journey to the Center of the Earth* [New Line] (Real D, Dolby 3D)
- *Hannah Montana & Miley Cyrus: Best of Both Worlds Concert* [Disney] (Real D, 600+ locations)
- *Bolt* [Disney] (Real D)

2009

- *My Bloody Valentine 3D* [Lionsgate] (Real D)
- *Jonas Brothers: The 3D Concert Experience* (Real D)
- *Coraline* [Universal, Focus Features] (Real D)
- *Monsters vs. Aliens* [Dreamworks, designed in Stereoscopic 3D] (IMAX 3D, Real D)
- *Up* [Disney-Pixar] (Real D)
- *Ice Age: Dawn of the Dinosaurs* [Fox] (Real D)
- *G-Force* [Disney, post-converted to 3D] (Real D, Dolby 3D)
- *The Final Destination* [New Line, shot in HD 3D] (Real D)
- *Cloudy with a Chance of Meatballs* (Sony) (Real D)
- Toy Story/Toy Story 2 Re-release [Disney] (Real D)
- *A Christmas Carol* [Disney] (IMAX 3D, Real D)
- *Avatar* [Fox, shot in 3D Fusion Camera System] (IMAX 3D, Real D, Dolby 3D, XPan 3D...in 2000+ 3D screens)

2010

- *Alice in Wonderland* [Disney, post-converted to 3D] (IMAX 3D, Real D) – March 5
- *How to Train Your Dragon* [Paramount/Dreamworks, designed in stereoscopic 3D] (IMAX 3D,

2011

- *The Green Hornet* [mostly post-converted to 3D] (IMAX 3D, Real D) – January 14
- *Sanctum* (IMAX 3D, Real D) - February 4
- *Gnomeo and Juliet* (Real D) –

Real D) – March 26

- *Clash of the Titans* [Legendary Pictures, post-converted to 3D) (Real D) – April 2
- *StreetDance 3D* [Vertigo Films, filmed in 3D (Real D) - May 21
- *Shrek Forever After* [Paramount/Dreamworks, designed in stereoscopic 3D] (IMAX 3D, Real D) – May 21
- *Toy Story 3* [Disney/Pixar] (IMAX 3D, Real D) – June 18
- *The Last Airbender* [Paramount, post-converted to 3D] (Real D) – July 1
- *Despicable Me* [Universal] (Real D) – July 9
- *Cats & Dogs: The Revenge of Kitty Galore* [Warner Bros., post-converted to 3D] (Real D) – July 30
- *Step Up 3D* [Touchstone] (Real D, Dolby 3D, Xpan 3D) – August 6
- *Piranha 3D* [Dimension, post-converted to 3D] (Real D) – August 20
- *Avatar* (Extended Re-Release, only in 3D) [Fox] (IMAX 3D, Real D) – August 27
- *Resident Evil: Afterlife* [Screen Gems, shot with 3D fusion camera system] (IMAX 3D, Real D) – September 10
- *Alpha and Omega* [Lionsgate] (Real D) – September 17
- *Legend of the Guardians: The Owls of Ga'Hoole* [Warner Bros.] (IMAX 3D, Real D) – September 24
- *My Soul to Take* [Universal, post-converted to 3D] (Real D) – October 8
- *Jackass 3D* [Paramount Pictures/MTV Films, filmed in 3D] (Real D) – October 15
- *Saw 3D* [Lionsgate, filmed in 3D] (Real D) – October 29
- *Megamind*

February 11

- *Justin Bieber: Never Say Never* (Real D) - February 11
- *Drive Angry* (Real D) – February 25
- *Mars Needs Moms!* (IMAX 3D, Real D) – March 11
- *Rio* (Real D) – April 15
- *3D Sex and Zen: Extreme Ecstasy* - May 1
- *Thor* [post-converted to 3D] (Real D) – May 6
- *Priest* [post-converted to 3D] (Real D) – May 13
- *Pirates of the Caribbean: On Stranger Tides* (IMAX 3D, Real D) – May 20
- *Kung Fu Panda 2* (IMAX 3D, Real D) – May 27
- *Green Lantern* [post-converted to 3D] (Real D) – June 17
- *Cars 2* (IMAX 3D, Real D) – June 24
- *Transformers: Dark of the Moon* (IMAX 3D,Real D) – July 1
- *Harry Potter and the Deathly Hallows* (Part 2 of 2) [Warner Bros., post-converted to 3D] (IMAX 3D, Real D) – July 15
- *Captain America: The First Avenger* [post-converted to 3D] (IMAX 3D, Real D) – July 22
- *The Smurfs* (IMAX 3D, Real D) – August 3
- *Conan the Barbarian* - August 19
- *Fright Night* (IMAX 3D, Real D) – August 19
- *Spy Kids 4: All the Time in the World* (IMAX 3D, Real D) – August 19
- *Final Destination 5* (IMAX 3D, Real D) – August 26
- *Shark Night 3D* - September 2
- *Piranha 3DD* (Real D) - September 16
- *A Dolphin's Tale* (IMAX 3D, Real D) – September 23

[Paramount/Dreamworks, designed in stereoscopic 3D] (IMAX 3D, Real D) – November 5
- *Battle Royal* 3D Re-Release [Toei Company] - November 20
- *Tangled* [Disney] (Real D) – November 24
- *The Chronicles of Narnia: The Voyage of the Dawn Treader* [Fox, post-converted to 3D] (Real D) – December 10
- *Tron: Legacy* [Disney] (IMAX 3D, Real D, Dolby 3D) – December 17
- *Yogi Bear* [Warner Bros., shot with 3D fusion camera system] (Real D) – December 17
- *Gulliver's Travels* [Fox, post-converted to 3D] (Real D) – December 25
- *Battle of Warsaw 1920* (IMAX 3D, Real D) - September 26
- *The Three Musketeers* – October 14
- *Contagion* (IMAX 3D, Real D) – October 21
- *Puss in Boots* (IMAX 3D, Real D) – November 4
- *Immortals* (IMAX 3D, Real D) - November 11
- *Happy Feet 2* (Real D) – November 18
- *Arthur Christmas* (IMAX 3D, Real D) – November 23
- *Hugo Cabret* (Real D) – December 9
- *Alvin and the Chipmunks: Chipwrecked* (Real D) – December 16
- *The Adventures of Tintin: The Secret of the Unicorn* (IMAX 3D, Real D) – December 23
- *The Cabin in the Woods* [post-converted to 3D] (Real D) – TBA
- *Journey 2: The Mysterious Island* – TBA

2012

- *Ice Age: Continental Drift* - July 13, 2012
- *Wrath of the Titans* 3D (Real D) - March 30, 2012
- *Titanic* 3D Re-Release (IMAX 3D Real D) – April 27, 2012
- *Men in Black III* (Real D) - May 25, 2012
- *Star Wars Episode I: The Phantom Menace* 3D Re-Release (Real D) - Late 2012
- *Yellow Submarine* (Real D) - TBA 2012
- *Spider-Man (2012 film)*

2013

- *Star Wars Episode II: Attack of the Clones* 3D Re-Release (Real D) - TBA 2013

2014

- *Avatar 2* [Fox, shot in 3D Fusion Camera System] (IMAX 3D, Real D, Dolby 3D, XPan 3D...in 2000+ 3D screens)
- *Star Wars Episode III: Revenge of the Sith* 3D Re-Release (Real D) - TBA 2014

2015

- *Avatar 3* [Fox, shot in 3D Fusion Camera System] (IMAX 3D, Real D, Dolby 3D, XPan 3D...in 2000+ 3D screens)
- *Star Wars Episode IV: A New Hope* 3D Re-Release (Real D) - TBA 2015

2016

- *Star Wars Episode V: The Empire Strikes Back* 3D Re-Release - TBA 2016

2017

- *Star Wars Episode VI: Return of the Jedi* 3D Re-Release - TBA 2017

World 3-D Expositions

In September 2003, Sabucat Productions organized the first World 3-D Exposition, celebrating the 50th anniversary of the original craze. The Expo was held at Grauman's Egyptian Theatre. During the two-week festival, over 30 of the 50 "golden era" stereoscopic features (as well as shorts) were screened, many coming from the collection of film historian and archivist Robert Furmanek, who had spent the previous 15 years painstakingly tracking down and preserving each film to its original glory. In attendance were many stars from each film, respectively, and some were moved to tears by the sold-out seating with audiences of film buffs from all over the world who came to remember their previous glories.

In May 2006, the second World 3-D Exposition was announced for September of that year, presented by the 3-D Film Preservation Fund. Along with the favorites of the previous exposition were newly discovered features and shorts, and like the previous Expo, guests from each film. Expo II was announced as being the locale for the world premiere of several films never before seen in 3-D, including *The Diamond Wizard* and the Universal short, *Hawaiian Nights* with Mamie Van Doren and Pinky Lee. Other "re-premieres" of films not seen since their original release in stereoscopic form included *Cease Fire!*, *Taza, Son of Cochise*, *Wings of the Hawk*, and *Those Redheads From Seattle*. Also shown were the long-lost shorts *Carmenesque* and *A Day in the Country* (both 1953) and William Van Doren Kelley's two *Plasticon* shorts (1922 and 1923).

Criticism

> “ After *Toy Story*, there were 10 really bad CG movies because everybody thought the success of that film was CG and not great characters that were beautifully designed and heartwarming. Now, you've got ”

> people quickly converting movies from 2D to 3D, which is not what we did. They're expecting the same result, when in fact they will probably work against the adoption of 3D because they'll be putting out an inferior product.
>
> — *Avatar* director James Cameron

Most of the cues required to provide humans with relative depth information are already present in traditional 2D films. For example, closer objects occlude further ones, distant objects are desaturated and hazy relative to near ones, and the brain subconsciously "knows" the distance of many objects when the height is known (e.g. a human figure subtending only a small amount of the screen is more likely to be 2 m tall and far away than 10 cm tall and close). In fact, only two of these depth cues are not already present in 2D films: stereopsis (or parallax) and the focus of the eyeball (accommodation).

3D film-making addresses accurate presentation of stereopsis but not of accommodation, and therefore is insufficient in providing a complete 3D illusion. However, promising results from research aimed at overcoming this shortcoming were presented at the 2010 Stereoscopic Displays and Applications conference in San Jose, U.S.

Motion sickness, in addition to other health concerns, are more easily induced by 3-D presentations.

Film critic Mark Kermode argued that 3d adds "not that much" of value to a film, and said that, while he liked *Avatar*, the many impressive things he saw in the movie had nothing to do with 3-D.

Film critic Roger Ebert has repeatedly criticized 3-D film as being "too dim" (due to the polarized-light technology using only half the light for each eye), sometimes distracting or even nausea-inducing, and argues that it is an expensive technology that adds nothing of value to the movie-going experience (since 2-D movies already provide a sufficient illusion of 3-D). While Ebert is "not opposed to 3-D as an option", he opposes it as a replacement for traditional film, and prefers 2-D techologies such as MaxiVision48 that improve image area/resolution and frames per second.

Another major criticism is that many of the movies in 21st century to date were not filmed in 3-D, but converted after filming. Filmmakers who have criticized this process include Michael Bay and James Cameron, the latter whose film *Avatar* (created in 3-D from the ground up) is largely credited with the revival of 3-D.

Director Christopher Nolan has criticised the notion that traditional film does not allow depth perception, saying "I think it's a misnomer to call it 3D versus 2D. The whole point of cinematic imagery is it's three dimensional... You know 95% of our depth cues come from occlusion, resolution, color and so forth, so the idea of calling a 2D movie a '2D movie' is a little misleading." Nolan also criticised that shooting on the required digital video does not offer a high enough quality image and that 3D cameras cannot be equipped with prime lenses.

Chapter- 4

Digital Video

Digital video is a type of video recording system that works by using a digital rather than an analog video signal.

History

Starting in the late 1970s to the early 1980s, several types of video production equipment- such as time base correctors (TBC) and digital video effects (DVE) units (two of the latter being the Ampex ADO, and the NEC DVE) were introduced that operated by taking a standard analog video input and digitizing it internally. This made it easier to either correct or enhance the video signal, as in the case of a TBC, or to manipulate and add effects to the video, in the case of a DVE unit. The digitized and processed clip from these units would then be converted back to standard analog video.

Later on in the 1970s, manufacturers of professional video broadcast equipment, such as Bosch (through their Fernseh division), RCA, and Ampex developed prototype digital videotape recorders in their research and development labs. Bosch's machine used a modified 1" Type B transport, and recorded an early form of CCIR 601 digital video. None of these machines from these manufacturers were ever marketed commercially, however.

Digital video was first introduced commercially in 1986 with the Sony D-1 format, which recorded an uncompressed standard definition component video signal in digital form instead of the high-band analog forms that had been commonplace until then. Due to its expense, D-1 was used primarily by large television networks. It would eventually be replaced by cheaper systems using compressed data, most notably Sony's Digital Betacam (still heavily used as a field recording format by professional television producers) that were introduced into the network's studios.

One of the first digital video products to run on personal computers was *PACo: The PICS Animation Compiler* from The Company of Science & Art in Providence, RI, which was developed starting in 1990 and first shipped in May 1991. PACo could stream unlimited-length video with synchronized sound from a single file on CD-ROM. Creation required a Mac; playback was possible on Macs, PCs, and Sun Sparcstations. In 1992, Bernard Luskin, Philips Interactive Media, and Eric Doctorow, Paramount Worldwide Video, successfully put the first fifty videos in digital MPEG 1 on CD, developed the packaging and launched movies on CD, leading to advancing versions of MPEG, and to DVD.

QuickTime, Apple Computer's architecture for time-based and streaming data formats appeared in June, 1991. Initial consumer-level content creation tools were crude, requiring an analog video source to be digitized to a computer-readable format. While low-quality at first, consumer digital video increased rapidly in quality, first with the introduction of playback standards such as MPEG-1 and MPEG-2 (adopted for use in television transmission and DVD media), and then the introduction of the DV tape format allowing recording direct to digital data and simplifying the editing process, allowing non-linear editing systems to be deployed cheaply and widely on desktop computers with no external playback/recording equipment needed. The widespread adoption of digital video has also drastically reduced the bandwidth needed for a high definition television signal (with HDV and AVCHD, as well as several commercial variants such as DVCPRO-HD, all using less bandwidth than a standard definition analog signal) and Tapeless camcorders based on flash memory and often a variant of MPEG-4.

Overview of basic properties

Digital video comprises a series of orthogonal bitmap digital images displayed in rapid succession at a constant rate. In the context of video these images are called **frames**. We measure the rate at which frames are displayed in **frames per second (FPS)**.

Since every frame is an orthogonal bitmap digital image it comprises a raster of **pixels**. If it has a width of **W** pixels and a height of **H** pixels we say that the **frame size** is W*x*H.

Pixels have only one property, their color. The color of a pixel is represented by a fixed number of bits. The more bits the more subtle variations of colors can be reproduced. This is called the **color depth (CD)** of the video.

An example video can have a **duration (T)** of 1 hour (3600*sec*), a frame size of 640x480 *(WxH)* at a color depth of 24*bits* and a frame rate of 25*fps*. This example video has the following properties:

- **pixels per frame** = 640 * 480 = 307,200
- **bits per frame** = 307,200 * 24 = 7,372,800 = 7.37*Mbits*
- **bit rate (BR)** = 7.37 * 25 = 184.25***Mbits/sec***
- **video size (VS)** = 184*Mbits/sec* * 3600*sec* = 662,400*Mbits* = 82,800*Mbytes* = 82.8***Gbytes***

The most important properties are *bit rate* and *video size*. The formulas relating those two with all other properties are:

```
BR = W * H * CD * FPS
VS = BR * T = W * H * CD * FPS * T
  (units are:  BR in bit/s,  W and H in pixels,  CD in bits,  VS in
bits,  T in seconds)
```

while some secondary formulas are:

```
pixels_per_frame  = W * H
pixels_per_second = W * H * FPS
bits_per_frame    = W * H * CD
```

Regarding Interlacing

In interlaced video each *frame* is composed of two *halves of an image*. The first half contains only the odd-numbered lines of a full frame. The second half contains only the even-numbered lines. Those halves are referred to individually as *fields*. Two consecutive fields compose a full frame. If an interlaced video has a frame rate of 15 frames per second the field rate is 30 fields per second. All the properties and formulas discussed here apply equally to interlaced video but one should be careful not to confuse the fields per second rate with the frames per second rate.

Properties of compressed video

The above are accurate for uncompressed video. Because of the relatively high bit rate of uncompressed video, video compression is extensively used. In the case of compressed video each frame requires a small percentage of the original bits. Assuming a compression algorithm that shrinks the input data by a factor of **CF**, the bit rate and video size would equal to:

```
BR = W * H * CD * FPS / CF
VS = BR * T / CF
```

Please note that it is not necessary that all frames are equally compressed by a factor of CF. In practice they are not, so CF is the *average* factor of compression for *all* the frames taken together.

The above equation for the bit rate can be rewritten by combining the compression factor and the color depth like this:

```
BR = W * H * ( CD / CF ) * FPS
```

The value **(CD / CF)** represents the **average bits per pixel (BPP)**. As an example, if we have a color depth of 12bits/pixel and an algorithm that compresses at 40x, then BPP equals 0.3 (12/40). So in the case of compressed video the formula for bit rate is:

```
BR = W * H * BPP * FPS
```

In fact the same formula is valid for uncompressed video because in that case one can assume that the "compression" factor is 1 and that the average bits per pixel equal the color depth.

More on bit rate and BPP

As is obvious by its definition bit rate is a measure of the rate of information content of the digital video stream. In the case of uncompressed video, bit rate corresponds directly to the quality of the video (remember that bit rate is proportional to every property that affects the video quality). Bit rate is an important property when transmitting video because the transmission link must be capable of supporting that bit rate. Bit rate is also important when dealing with the storage of video because, as shown above, the video size is proportional to the bit rate and the duration. Bit rate of uncompressed video is too high for most practical applications. Video compression is used to greatly reduce the bit rate.

BPP is a measure of the efficiency of compression. A true-color video with no compression at all may have a BPP of 24 bits/pixel. Chroma subsampling can reduce the BPP to 16 or 12 bits/pixel. Applying jpeg compression on every frame can reduce the BPP to 8 or even 1 bits/pixel. Applying video compression algorithms like MPEG1, MPEG2 or MPEG4 allows for fractional BPP values.

Constant bit rate versus variable bit rate

As noted above BPP represents the *average* bits per pixel. There are compression algorithms that keep the BPP almost constant throughout the entire duration of the video. In this case we also get video output with a constant bit rate (CBR). This CBR video is suitable for real-time, non-buffered, fixed bandwidth video streaming (e.g. in videoconferencing).

Noting that not all frames can be compressed at the same level because quality is more severely impacted for scenes of high complexity some algorithms try to constantly adjust the BPP. They keep it high while compressing complex scenes and low for less demanding scenes. This way one gets the best quality at the smallest average bit rate (and the smallest file size accordingly). Of course when using this method the bit rate is variable because it tracks the variations of the BPP.

Technical overview

Standard film stocks such as 16 mm and 35 mm record at 24 frames per second. For video, there are two frame rate standards: NTSC, which shoot at 30/1.001 (about 29.97) frames per second or 59.94 fields per second, and PAL, 25 frames per second or 50 fields per second.

Digital video cameras come in two different image capture formats: interlaced and progressive scan.

Interlaced cameras record the image in alternating sets of lines: the odd-numbered lines are scanned, and then the even-numbered lines are scanned, then the odd-numbered lines are scanned again, and so on. One set of odd or even lines is referred to as a "field", and a consecutive pairing of two fields of opposite parity is called a *frame*.

A progressive scan video camera records each frame as distinct, with all scan lines being captured at the same moment in time. Thus, interlaced video captures samples the scene motion twice as often as progressive video does, for the same number of frames per second.

Progressive-scan camcorders generally produce a slightly sharper image. However, motion may not be as smooth as interlaced video which uses 50 or 59.94 fields per second, particularly if they employ the 24 frames per second standard of film. (Note that even though the digital video format only allows for 29.97 interlaced frames per second [or 25 for PAL], 24 frames per second progressive video is possible through a technique called 3:2 pulldown)

Digital video can be copied with no degradation in quality. No matter how many generations of a digital source is copied, it will still be as clear as the original first generation of digital footage.

Digital video can be manipulated and edited to follow an order or sequence on an NLE, or non-linear editing workstation, a computer-based device intended to edit video and audio. More and more, videos are edited on readily available, increasingly affordable consumer-grade computer hardware and software. However, such editing systems require ample disk space for video footage. Digital video recorded with standard consumer-grade DV/DVCPRO compression takes up about 250 megabytes per minute or 13 gigabytes per hour.

Digital video has a significantly lower cost than 35 mm film. The tape stock itself is very inexpensive — about $3 for a 60 minute MiniDV tape, in bulk, as of December, 2005. Digital video also allows footage to be viewed on location without the expensive chemical processing required by film. By comparison, 35 mm film stock costs about $1000 per minute, including processing.

Digital video is used outside of movie making. Digital television (including higher quality HDTV) started to spread in most developed countries in early 2000s. Digital video is also used in modern mobile phones and video conferencing systems. Digital video is also used for Internet distribution of media, including streaming video and peer-to-peer movie distribution.

Many types of video compression exist for serving digital video over the internet and on optical disks. The file sizes of digital video used for professional editing are generally not practical for these purposes, and the video requires further compression with codecs such as the Windows Media format, MPEG2, MPEG4, Real Media, and more recently H.264. Probably the most widely used formats for delivering video over the internet are MPEG4 and Windows Media, while MPEG2 is used almost exclusively for DVDs, providing an exceptional image in minimal size but resulting in a high level of CPU consumption to decompress.

While still images can have any number of pixels, the video community defines various standards for resolution. A path through devices that use incompatible resolutions may require that video be rescaled several times from capture to ultimate audience display.

As of 2007, the highest resolution demonstrated for digital video generation is 33 megapixels (7680 x 4320) at 60 frames per second ("Ultra High Definition Television"), though this has only been demonstrated in special laboratory settings. The highest speed is attained in industrial and scientific high speed cameras that are capable of filming 1024x1024 video at up to 1 million frames per second for brief periods of recording.

Poster frame

A **poster frame** or **preview frame** is a selected frame of the video used as a thumbnail.

Interfaces and cables

Many interfaces have been designed specifically to handle the requirements of uncompressed digital video (at roughly 400 Mbit/s):

- Serial Digital Interface
- FireWire
- High-Definition Multimedia Interface
- Digital Visual Interface
- Unified Display Interface
- DisplayPort
- USB
- Digital component video

The following interface has been designed for carrying MPEG-Transport compressed video:

- DVB-ASI

Compressed video is also carried using UDP-IP over Ethernet. Two approaches exist for this:

- Using RTP as a wrapper for video packets
- 1-7 MPEG Transport Packets are placed directly in the UDP packet

Storage formats

Encoding

All current formats, which are listed below, are PCM based.

- CCIR 601 used for broadcast stations
- MPEG-4 good for online distribution of large videos and video recorded to flash memory
- MPEG-2 used for DVDs, Super-VCDs, and many broadcast television formats
- MPEG-1 used for video CDs
- H.261
- H.263
- H.264 also known as *MPEG-4 Part 10*, or as *AVC*, used for Blu-ray Discs and some broadcast television formats

Tapes

- Betacam, BetacamSP, Betacam SX, Betacam IMX, Digital Betacam, or DigiBeta — Commercial video systems by Sony, based on original Betamax technology
- HDCAM was introduced by Sony as a high-definition alternative to DigiBeta.
- D1, D2, D3, D5, D9 (also known as Digital-S) — various SMPTE commercial digital video standards
- DV, MiniDV — used in most of today's videotape-based consumer camcorders; designed for high quality and easy editing; can also record high-definition data (HDV) in MPEG-2 format
- DVCAM, DVCPRO — used in professional broadcast operations; similar to DV but generally considered more robust; though DV-compatible, these formats have better audio handling.
- DVCPRO50, DVCPROHD support higher bandwidths as compared to Panasonic's DVCPRO.
- Digital8 — DV-format data recorded on Hi8-compatible cassettes; largely a consumer format
- MicroMV — MPEG-2-format data recorded on a very small, matchbook-sized cassette; obsolete
- D-VHS — MPEG-2 format data recorded on a tape similar to S-VHS

Discs

- VCD
- DVD
- Blu-ray Disc

Chapter- 5

Digital Cinema Package

A **Digital Cinema Package** (**DCP**) is a collection of digital files used to store and convey Digital cinema (DC) audio, image, and data streams.

The term has been defined by Digital Cinema Initiatives, LLC in their recommendations for packaging of DC contents. Following to the recommendations, general practice adopts a file structure that is organized into a number of (generally) multi-gigabyte size Material eXchange Format (MXF) files, which are separately used to store audio and video streams, and auxiliary index files in XML format. One such file, the Composition Playlist, defines the playback order of Digital Cinema Packages during presentation.

The MXF files contain streams that are compressed, encoded, and encrypted, in order to reduce the huge amount of required storage and to protect from unauthorized use. The image part is JPEG 2000 compressed, whereas the audio part is linear PCM. The adopted (optional) encryption standard is AES 128 bit in CBC mode.

SMPTE standards are used to conform the recommendations among different tool vendors and producers.

Technical specifications

The DCP root folder (in the storage medium) contains a number of files, some used to store the image and audio contents, and some other used to organize and manage the whole playlist.

Picture MXF files

Picture contents are stored in one or more *reels* corresponding to one or more MXF files. Each reel contains pictures as MPEG-2 or JPEG 2000 essence, depending on the adopted codec. MPEG-2 is no longer compliant with the DCI specification. JPEG 2000 is the only accepted compression format.

- Supported frame rates are 24, and 48 frames per second. DCPs conforming to older specifications could be encoded at 25fps. This is now outdated.

- Maximum frame size is 2048x1080 for 2K DC, and 4096x2160 for 4K DC. Common formats are:
  - Flat (1998x1080 or 3996x2160), ~1.85:1 aspect ratio
  - Scope (2048x858 or 4096x1716), ~2.39:1 aspect ratio
  - 16:9 (1920x1080 or 3840x2160), although not officially supported by the DCI specification, this aspect ratio is commonly used, especially for content originally made for HDTV.
- 12 bits per pixel precision (36 bits total)
- XYZ colorspace
- Maximum bit rate is 250 Mbps (1.3 MBytes per frame at 24 fps)

Sound MXF files

Sound contents are stored in reels, too, corresponding to picture reels in number and duration. In case of multilingual features, separate reels are required to convey different languages. Each file contains linear PCM essence.

- Sampling rate is 48,000 or 96,000 samples per second
- Sample precision of 24 bits
- Linear mapping (no companding)
- Up to 12 independent channels.

Asset Map file

List of all files included in the DCP, in XML format.

Composition Playlist file

The presentation order is saved in XML format in this file; each picture and sound reel is identified by its UUID. In the following example, a reel is composed by picture and sound:

```
<Reel>
 <Id>urn:uuid:632437bc-73f9-49ca-b687-fdb3f98f430c</Id>
 <AssetList>
  <MainPicture>
   <Id>urn:uuid:46afe8a3-50be-4986-b9c8-34f4ba69572f</Id>
   <EditRate>24 1</EditRate>
   <IntrinsicDuration>340</IntrinsicDuration>
   <EntryPoint>0</EntryPoint>
   <Duration>340</Duration>
   <FrameRate>24 1</FrameRate>
   <ScreenAspectRatio>2048 858</ScreenAspectRatio>
  </MainPicture>
  <MainSound>
   <Id>urn:uuid:1fce0915-f8c7-48a7-b023-36e204a66ed1</Id>
   <EditRate>24 1</EditRate>
   <IntrinsicDuration>340</IntrinsicDuration>
   <EntryPoint>0</EntryPoint>
```

```
   <Duration>340</Duration>
  </MainSound>
 </AssetList>
</Reel>
```

Packing List file

All files in the composition are hashed and their hash is stored here, in XML format. This file is generally used during ingestion in DC server to verify if data have been corrupted or tampered in some way. For example, an MXF picture reel is identified by the following `<asset>` element:

```
<Asset>
 <Id>urn:uuid:46afe8a3-50be-4986-b9c8-34f4ba69572f</Id>
 <Hash>iqZ3X7TdAjAqniOxT2/hj66VCUU=</Hash>
 <Size>210598692</Size>
 <Type>application/x-smpte-mxf;asdcpKind=Picture</Type>
</Asset>
```

Volume Index file

A single DCP may be stored in more than one medium (e.g., multiple hard disks). This file is used to identify the volume order in the series.

3D DCP

The very same format shown before is also used to store stereoscopic (3D) contents. In this case, 48 frames per second are used, with frames alternating for left eye and right eye pictures. Since the maximum bit rate is always 250 Mbit/s, this results in a net 125 Mbit/s for single frame, but the visual quality decrease is generally unnoticeable.

DCP Creation

Most film producers and distributors rely on digital cinema encoding facilities to produce and quality control check a digital cinema package before release. Facilities follow strict guidelines set out in the DCI recommendations to ensure compatibility with all digital cinema equipment. For bigger studio release films, the facility will usually create a DCDM (Digital Cinema Distribution Master).

A DCDM is similar to DCP, only the frames are in either DPX or TIFF format and both sound and picture are not yet wrapped into MXF files. A DCP can be encoded directly from a DCDM. A DCDM is useful for archiving purposes and also facilities can share them for international re-versioning purposes. They can easily be turned into alternative version DCPs for foreign territories. For smaller release films, the facility will usually skip the creation of a DCDM and instead encode directly from the DSM (Digital Source Master) the original film supplied to the encoding facility. A DSM can be supplied in a multitude of formats and colour spaces. For this reason, the encoding facility need to have extensive knowledge in colour space handling including, on occasion, the use of 3D LUTs to carefully match the look of the finished DCP to a celluloid film print. This can be a highly involved process in which the DCP and the film print are "butterflied" (shown side by side) in a highly calibrated cinema.

Less demanding DCPs are encoded from tape formats such as HDCAM SR. Quality control checks are always performed in calibrated cinemas and carefully checked for errors. QC checks are often attended by colourists, directors, sound mixers and other personnel to check for correct picture and sound reproduction in the finished DCP.

The Inter-Society Digital Cinema Forum publish an online list of the digital cinema encoding facilities known to them. Each facility is given a "facility code" which is used to identify them in the DCP naming convention.

DCP delivery methods

The most common method uses a specialist hard disk (most commonly the CRU DX115) designed specifically for digital cinema servers to ingest from. These hard drives were originally designed for military use but have since been adopted by digital cinema for their hard wearing and reliable characteristics. The hard drives are usually formatted in the Linux EXT2 or EXT3 format. NTFS is occasionally used but is generally not considered reliable as some Linux based digital cinema servers (such as those made by Dolby and Sony) are unable to read this format. Hard drive units are normally hired from a digital cinema encoding company, sometimes in quantities of thousands. Drives are commonly shipped in protective hard cases. The drives are delivered via Express Courier to the exhibition site. Other, less common methods adopt a full digital delivery, using either dedicated satellite links or high speed Internet connections.

DCP creation tools

- CineCert AS-DCP File Access Library : open source, BSD-like license, windows/mac/linux, command line, needs separate codec, no XML files creation
- OpenDCP : open source, GPL, J2K conversion, XYZ color conversion, MXF creation, XML file generation.
- opencinematools : open source, BSD license, windows/mac/linux, command line/GUI, needs separate codec, no MXF files creation
- DVS Clipster : commercial, windows, GUI
- Doremi CineAsset : commercial, windows/mac, GUI
- Qube QubeMaster Pro : commercial, windows, GUI
- Fraunhofer IIS easyDCP Creator : commercial, windows/mac, GUI

Chapter- 6

Digital on-screen Graphic

In a typical digital on screen graphic, the station's logo appears in a corner of the screen.

A station may also display a clock and temperature alongside their digital on screen graphic.

A **digital on-screen graphic** (originally known as **digitally-originated graphic**) (known in the UK and New Zealand by the acronym **DOG**; in the US and Canada as a **bug**; and in Australia as a **watermark**) is a watermark-like station logo that many television broadcasters overlay over a portion of the screen-area of their programs to identify the channel. They are thus a form of permanent visual station identification, increasing brand recognition and asserting ownership of the video signal. In some cases, the graphic also shows the name of the current program. Some networks use an on-screen graphic to advertise later programs in the day's television schedule—this is generally displayed after the opening, during in-program credits, and when returning from a commercial break.

The graphic identifies the source of programming even if it is time-shifted—that is, recorded to videotape, DVD, or via a digital personal video recorder such as TiVo by possibly station identification. Many of these technologies allow viewers to skip or omit traditional between-programming station identification; thus the use of a DOG enables the station or network to enforce brand-identification even when standard commercials are skipped. DOG watermarking also helps minimize off-the-air copyright infringement (for example the distribution of a current series' episodes on DVD): the watermarked content is easily differentiated from "official" DVD releases, and can help law-enforcement efforts by identifying not only the station an illegally copied broadcast was captured from, but usually the actual date of the broadcast as well.

Usage

Many news broadcasters place a clock alongside their DOG, giving it legitimacy if it is moved into an unorthodox position, such as the bottom left. In the United States, Canada, Australia, and New Zealand, DOGs may also include the show's parental guideline rating. In Australia, this is known as a Program Return Graphic (PRG). It has also become custom to place text advertising other programs on the network above the station's logo.

During televised sports events, a DOG may also display a few game-related statistics such as the current score. This has led many people in Canada and the United States to refer to it as a **score bug**.

Europe

United Kingdom

In the UK, DOGs most commonly appear in the top-left hand corner on British channels. DOGs were first used on satellite and cable television systems in their early days, when broadcasts were unmarked. Channel 5 was the first to use DOGs on an analogue terrestrial channel in 1997. The DOG was originally very bright and noticeable, and was soon toned down. Channel 5 said that the DOG was used to assist viewers in tuning to the new channel once its test transmissions had ceased. Following the rebrand to "five" in 2002 the DOG disappeared until October 2007.

The BBC has a DOG on each of its digital-only channels. In October 1998, it added DOGs to BBC One and Two but following a large number of complaints they were removed just two months later. The DOGs appear in the top left-hand corner on other channels except BBC News (which is bottom left and forms part of integrated information graphics) and its international counterpart, BBC World News. Whilst BBC One HD, BBC Four, BBC HD and BBC Parliament have static DOGs, the ones on BBC Three, CBBC and CBeebies alongside other channels such as Five and Nick Jr. feature moving elements. ITV uses DOGs on all its channels besides ITV1. UTV provide a DOG in the top left hand corner of the screen.

The logos on channels such as Sky Sports, Five, BBC Three, ITV2, 3 and 4, E4, E!, Disney XD, Sky Arts 1 and 2, Sky1, 2 and 3, The History Channel and More4 are almost transparent, whereas others like those on Comedy Central, Eurosport, Playhouse Disney, the UKTV channels, CITV, Virgin1, CBBC, CBeebies, the Discovery channels, Nick Jr., Nicktoons, Boomerang and Nickelodeon are bright and noticeable. Sky Movies, Film4 and Channel 4 do not use DOGs. Some stations display their on-screen graphics permanently. Sky1 and Dave are examples that remove them during commercials and trailers. In addition to a fixed (sometimes animated) motif, MTV includes the program title in the top-right hand corner. During widescreen programs, the DOGs on E4, 4Music and More4 stay in the far corner of the screen while most other channels keep theirs within the 4:3 "safe area".

On British digital systems such as Sky Digital and Freeview, where stations have a set EPG number and a name displayed across the bottom of the screen when changing channel, DOGs have been deemed unnecessary by some users. Despite this, broadcasters persist with the practice. In response to negative feedback, the BBC has responded, "We believe it is important to ensure that viewers can quickly identify when they are watching a BBC service." It reinforced this position in both 2008 and 2009 following continual complaints to its *Points of View* program, citing channel identification as the sole reason for the policy. In its website FAQs, Five's stated reason for its use of a DOG is that "the vast majority of channels carry them, most permanently and virtually every channel at some point has one during the day." However, on 21 October 2008, the BBC announced that it was removing the DOG from BBC HD for all films and most dramas, acknowledging that there was an "irritation factor". More recent additions are graphics which appear near the end of a program to tell the viewer what's up next, despite this information being available at a touch of a button on digital TV. Many viewers also find this practice annoying, distracting and unnecessary.

In the United Kingdom, score bugs are commonly known as scorebars. The first major British network to carry scorebars in their televised sports games was Sky. Other terrestrial networks followed suit, and all football games on the BBC, ITV and Five now use them. As in the United States, the scorebar is traditionally placed in the top left-hand corner of the screen. An exception occurred at the beginning of the 2007–08 football season, when Sky Sports experimented with a bar positioned bottom-left. However, this was not popular and by September it had been returned to the top-left of the screen.

Germany

In the 1980s, public broadcasters started to randomly show logos during programs to prevent video piracy, following the lead of Italian broadcasters RAI and Canale 5. After the first private stations emerged in 1984, permanently showing their logo most times, the public broadcasters soon followed. Today practically all TV stations show their logo during the programs and often these are an integral part of their design using fluent animations to make the transition between programs, previews and advertising, as well as displaying additional information such as teletext numbers or the name of the following program. Most logos are transparent during programming though some channels don't. (i.e. kabel eins uses a bright orange coloured logo.) Also the majority of the channels show their logo in either the top-left or top-right corner of the picture though there are exceptions (i.e. RTL II in the bottom-right or N24 logo in the bottom-left and date and time in the top-right).

Ireland

The Irish Language channel TnaG first used their DOG during simulcast of QVC and their coverage of the Oireachtas (Irish Parliament). In 1998 TV3 launch as Ireland's first commercial operator and the first Irish channel to permanently use a DOG in the Left hand corner of the screen. In 1999 TnaG re-branded as TG4 and began showing their logo during all programmes. In 2002 RTÉ introduce their DOG however it would only appear for 20 seconds at the beginning of each show and it was there to classify the suitability of the content of the show, in 2004 the dog became a permanent part of the on screen presentation for both RTÉ One and RTÉ Two. RTÉ's classification guide also appears for 20 seconds at the beginning of each show. RTÉ's, TG4's and Setanta Ireland's DOGs appear in the upper right hand corner of the screen, while TV3's DOGs appear in the bottom right hand corner of the screen. RTÉ and TV3 do not use their DOGs during news or current affairs programming.

Serbia

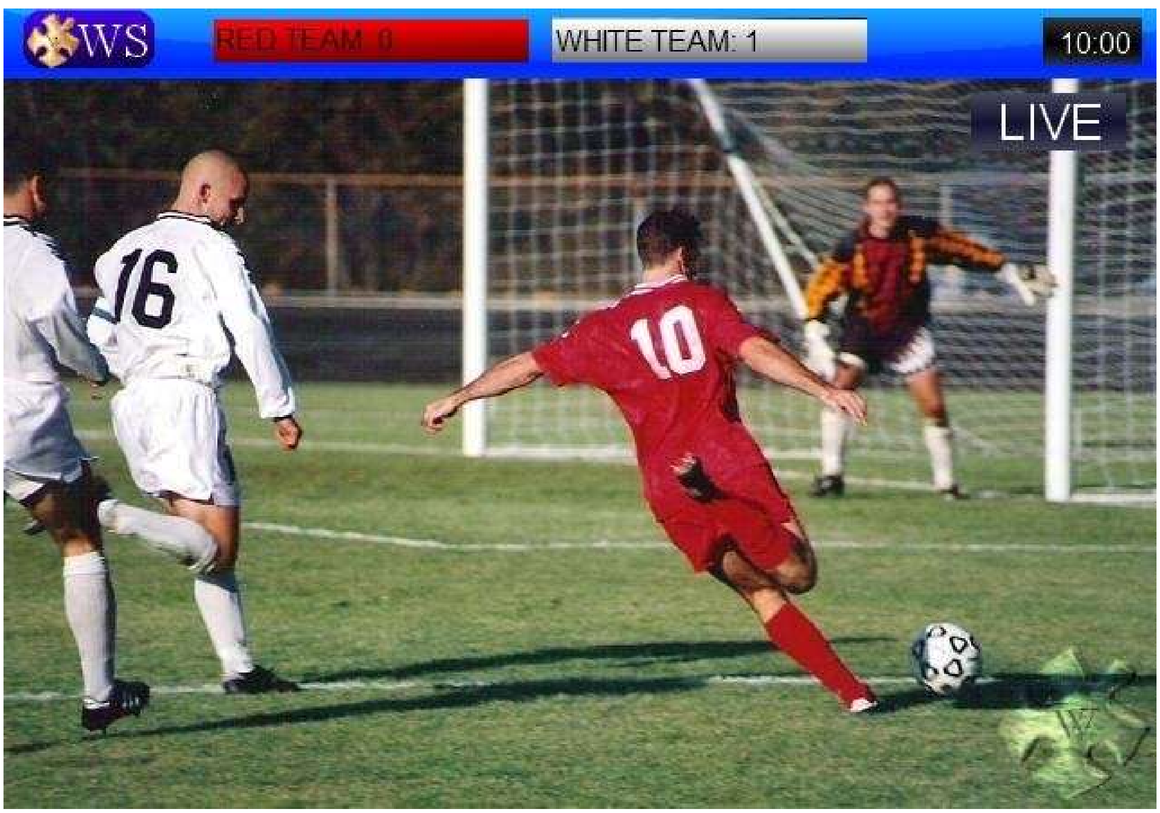
The Serbian national television RTS began showing logos in the early 1990s. Their logo was sometimes turned on manually during certain broadcasts but shortly afterwards remained permanently on-screen. One could notice how they were manually controlled, as the "logo-free" time during the begin of a program varied. Until around 1994/1995 their logos were opaque white and black, presumably due to being inserted into the analog CVBS signal just before being broadcast instead of a analog YUV, RGB or digital SDI signal, while in the mid-1990s they upgraded to colorized but still opaque logos. RTS' predecessor RTB (Radio Television of Belgrade) had DOGs of varying sizes, but rather than being introduced one after another they appear to have been used simultaneously at different broadcast sites. At least 3 different sizes and styles of their opaque black-and-white logo are known today. On the satellite channel "RTS-SAT" latin letters were used, but after the destruction of RTS headquarters in 1999 during a NATO airstrike, it could be noticed how the logo appeared to have been quickly re-drawn and was being inserted by different equipment as it varied in shape and size, presumably due to the fact that the original equipment used to insert it being destroyed. Today RTS has the same opaque color logo from 1999 on RTS-SAT and new translucent logos were introduced in the 2000s for the analog terrestrial programs. It is interesting, that old logos remain on most archived recordings presumably due to lack of a cleanfeed archiving policy in the past, as can be seen in the "Trezor" historical series:

Trivia: During a football victory in 1990, the logo jumped from the left to the right corner and back many times, presumably due to a technician playing with the DOG inserter out of happiness over the victory.

Most local and regional stations and some national commercial broadcasters (Pink, B92, Avala) in Serbia along with station logo also shows a digital clock below the logo.

North America

United States



A typical score bug on a televised sporting event will consist of the station logo alongside the current score of game, and other information, such as time elapsed.

The first network in the United States to produce a **score bug** was ABC, which used one on the telecast of the 1994 Purolator 500 NASCAR event. A transparent digit counted down the number of laps remaining in the race. A similar bug was used during ABC's telecast of the 1994 Indianapolis 500 and 1994 Brickyard 400. ABC also incorporated the

Sports Bug for their 1994 World Cup coverage, providing the time and score on the game as well as enabling advertiser sponsorship to broadcast games without interruptions. Later that fall, Fox introduced a full-score bug for its NFL coverage, known as the "FoxBox", as did cable network ESPN. ABC expanded theirs to *Monday Night Football* in 1997. CBS introduced theirs upon returning to the NFL in the fall of 1998, and NBC in 2001 during its coverage of the XFL.

The first **score banner**, which takes up the top of the screen, was used for minor league hockey broadcasts by SportsChannel New York in their coverage of the Albany River Rats of the American Hockey League during the National Hockey League lockout of 1994-95. It was the brainchild of director Joe O'Rourke, and was implemented by producer Roland Dratch and font coordinator Dave Katz. Fox then used the score banner for its NASCAR coverage in 2001. Fox then expanded the scoring banner to all sports. Fox Sports Net also uses a scoring banner for basketball, hockey, baseball and soccer coverage, as do many other local broadcasters of sporting events.

ABC introduced a Fox-like banner, but along the bottom of the screen, for *Monday Night Football* in 2005, its last year of the franchise. The network introduced a revised version February 5, 2006, during an NBA game, as well as during that day's presentation of Super Bowl XL, which quickly became used for all sports on the network. ABC returned to a bug in September when the sports division became ESPN on ABC. NBC also began using a scoring banner, along the bottom like ABC's, in 2005 for its coverage of Notre Dame football home game telecasts, which also quickly became used for all sports on the network except for hockey, where the banner runs atop the screen, which have been adapted by Canadian broadcasters, CBC, Rogers Sportsnet and TSN. The networks of Turner Broadcasting System used the traditional score bugs until they began broadcasting the 2007 Major League Baseball Division Series, in which they converted to a top screen banner. ESPN began using a banner starting with the 2006 FIFA World Cup and MLB Home Run Derby, a bottom-screen banner for NBA and AFL telecasts and in 2007, a top-screen banner for NASCAR and baseball telecasts, plus a center-screen bug for their Monday Night Football telecasts in 2006 and 2007 before switching to a bottom-screen banner in 2008. Starting in 2007, they added banners for college football and in college basketball telecasts. In addition, ESPN's college sports telecasts added two (lacrosse), three (college football) or five (college basketball) yellow stripes, representing the timeouts the team has left to the banner. Timeout indicators were also added for ESPN's *Monday Night Football* telecasts, beginning with Week 4 of the 2009 NFL season. In 2006, CBS began using a bottom-of-the-screen banner for NCAA Basketball telecasts but retained the traditional box for all NFL broadcasts, but as of 2009 uses a banner for college football and NFL games at the top of the screen. Sibling network CBS College Sports however, began using a top-screen banner for baseball in 2008, and since expanded to other sports, duplicating bottom screen banners for basketball. The one exception among all the networks is motor racing, as all of them will use scrolling banners for these races. In 2007, TBS began using a top-screen banner for postseason baseball broadcasts, and continued into the 2008 season, returning to a longer bug in 2009.

For the 2008 college football season, FSN adopted a new graphics package and reverted to the scoring bug on the top left-hand corner of the screen for football, hockey, and baseball, while on the bottom right-hand corner for basketball. Fox then adopted these graphics for its 2009 Major League Baseball telecasts.

Some type of continuous graphic indicating time, score or standings are now used in every major sport televised in the U.S., except golf. In that sport, leaderboards are still flashed on and off screen at regular intervals, with a full rundown every half hour or so. However, starting in 2008, the ESPN networks' golf coverage has included consistent use of scoring banners, often alternating between alphabetical scoring, leaderboard-style scoring, and single group scoring (which is often used when multiple notable players are in the same two or threesome).

The score bug used by TNT in the 2008-09 and 2009-10 seasons for NBA basketball games uses a highlight to indicate which team is winning. This feature is rare among in-game score graphics, even though the graphics for scores of completed games generally highlight the team that won.

From its inception, cable network VH1 commonly used a bug in the corner of the screen while broadcasting music videos for copyright purposes. MTV also did the same, beginning in 1993. MTV first began using a bug while videos were shown on the program *Beavis and Butt-head*, displaying the show's logo during the videos (but not Beavis and Butt-head's commentary of them).

Canada

CTV places their opaque logo over Fox's on-screen graphic during *American Idol*.

In Canada, networks and channels display logo bugs the same way as the UK and the US, with only minor differences.

How a Canadian TV network could place their logo if a US network's logo is already present.

Canadian networks often request the simultaneous substitution of programs on US networks. The imported feed is either a clean feed without a bug from the US broadcaster, or a direct US feed with the US network's bug present.

When the US network's bug is present, the Canadian broadcaster will either:

- cover up the logo with their own (opaque) logo - this strategy is used by CTVglobemedia's TV stations (the logo is normally grey), and NTV in Newfoundland), or
- "co-brand" the show by placing their logo in a different corner of the screen.

Asia

Many Asian stations use opaque logos, except in some countries such as Japan and South Korea, where logos are either translucent or not used at all. In some countries, such as Cambodia, China, Laos, India, Myanmar, Taiwan and Vietnam, many stations leave a logo on at all times, even during commercials and test cards. Some countries like Malaysia, Singapore, Hong Kong, Indonesia, Japan, Philippines and Thailand, usually remove the channel logo during commercial break and showing only the channel name during test card transmission. Most TV stations in Japan also show an onscreen digital clock, often in the upper left corner.

Connections with sponsor tags

Another graphic on television usually connected with sports (particularly in North America, though not in Europe) is the sponsor tag. It shows the logos of certain sponsors, accompanied by some background relevant to the game, the network logo, announcement and music of some kind.

Use in ham radio

In most countries, hams are required to periodically identify their amateur-TV transmission. Therefore they nowadays frequently overlay their callsign on the signal instead of having a paper card in the background. Most hams use for this purpose homebuilt devices or old consumer character generators. Only rarely one can see real graphics, as most of the time their callsign is written out in the typical "OSD font".

Live DOGs by hobbyists

One of the easiest and most sought-after devices used to generate DOGs by hobbyists is the 1980s vintage SONY XVT-500 video superimposer. This device can luma-key a signal, capture a still frame into memory and then overlay the keyed graphic in one of eight colors onto any CVBS signal. Another method commonly used by hobbyists and even low-budgeted TV stations in former times was Amiga computers with genlock interfaces.

Chapter- 7

Color Motion Picture Film

Color motion picture film refers to motion pictures in color. The first motion pictures were made with silver halide-based photographic emulsion on a clear base. The resulting image was projected in a range of blacks to whites, depending on the luminous intensity of the original subject.

With color motion picture film, not only is the luminance of a subject recorded, but the color of the subject, too. Whether the color is photographed on separate pieces of film or within the same emulsion, all color photography is synthesized through various parts of the image recording discrete spectra of light.

The earliest motion picture stocks were orthochromatic nitrate and recorded cyan (blue and green) light, but not red light. Recording all three major wavelengths of light required making film stock panchromatic nitrate to some degree.

Tinting and hand coloring

Since orthochromatic film stock hindered color photography in its beginnings, the first films with color in them utilized aniline dyes in order to create artificial color. Hand-colored films began in 1895 with Thomas Edison's hand-painted *Anabelle's Dance* made for his Kinetoscope viewers.

Many of the early filmmakers from the first ten years of film also used this method to some degree. George Méliès offered hand-painted prints of his own films at an additional cost over the black and white versions, including the visual-effects pioneering *A Trip to the Moon* (1902). The film had various parts of the film painted frame-by-frame by twenty-one women in Montreuil in a production-line method.

The first commercially successful stencil color process was introduced in 1905 by Pathé Frères. *Pathé Color* (renamed Pathéchrome in 1929) became one of the most accurate and reliable stencil coloring systems. It incorporated an original print of a film with sections cut by pantograph in the appropriate areas for up to six colors by a coloring machine with dye-soaked, velvet rollers. After a stencil had been made for the whole film, it was placed into contact with the print to be colored and run at high speed (60 feet per minute) through the coloring (staining) machine. The process was repeated for each set of stencils corresponding to a different color. By 1910, Pathé had over 400 women employed as stencilers in their Vincennes factory. Pathéchrome continued production through the 1930s.

A more common technique emerged in the early 1910s known as **film tinting**, a process in which either the emulsion or the film base is dyed, giving the image a uniform monochromatic color. This process was popular during the silent era, with specific colors employed for certain narrative effects (red for scenes with fire or firelight, blue for night, etc.).

A complementary process, called **toning**, replaces the silver particles in the film with metallic salts or mordanted dyes. This creates a color effect in which the dark parts of the image are replaced with a color (e.g., blue and white rather than black and white). Tinting and toning were sometimes applied together.

In the United States, St. Louis engraver Max Handschiegl and cinematographer Alvin Wyckoff created the Handschiegl Color Process, a stencil process first used in *Joan the Woman* (1917) directed by Cecil B. DeMille, and used in special effects sequences for films such as *The Phantom of the Opera* (1925). The process employed the principles of three-color lithography to tint films by machine.

Eastman Kodak introduced its own system of pre-tinted black-and-white film stocks called Sonochrome in 1929. The Sonochrome line featured films tinted in seventeen different colors including Peachblow, Inferno, Candle Flame, Sunshine, Purple Haze, Firelight, Azure, Nocturne, Verdante, Aquagreen, Caprice, Fleur de Lis, Rose Doree, and the neutral-density Argent, which kept the screen from becoming excessively bright when switching to a black-and-white scene.

Tinting and toning continued to be used well into the sound era. In the '30s and '40s, some western films were processed in a sepia-toning solution to evoke the feeling of old photographs of the day. Tinting was used as late as 1951 for Sam Newfield's sci-fi film *Lost Continent* for the green lost-world sequences. Alfred Hitchcock used a form of hand-coloring for the orange-red gun-blast at the audience in *Spellbound* (1945). Kodak's Sonochrome and similar pre-tinted stocks were still in production until the 1970s and were used commonly for custom theatrical trailers and snipes.

Physics of light and color

The principles on which color photography is based were first proposed by Scottish physicist James Clerk Maxwell in 1855 and presented at the Royal Society in London in 1861. By that time, it was known that light comprises a spectrum of different wavelengths that are perceived as different colors as they are absorbed and reflected by natural objects. Maxwell discovered that all natural colors in this spectrum may be reproduced with additive combinations of three primary colors - red, green, and blue - which, when equally mixed together, produce white light.

Between 1900 and 1935, dozens of natural color systems were introduced, although only a few were successful.

Additive color

The first color systems that appeared in motion pictures were additive color systems. Additive color was practical because no special color stock was necessary. Black and white film could be processed and used in both filming and projection. The various additive systems entailed the use of color filters on both the movie camera and projector. Additive color adds lights of the primary colors in various proportions to the projected image. Because of the limited amount of space to record images on film, and later because the lack of a camera that could record more than two strips of film at once, most early motion-picture color systems consisted of two colors, often red and green or red and blue.

Practical color in the motion picture business began with Kinemacolor, first introduced in 1906. This was a two-color system created in England by Edward R. Turner and George Albert Smith, and promoted by film pioneer Charles Urban's The Charles Urban Trading Company in 1908. It was used for a series of films including the documentary *With Our King and Queen Through India*, depicting the Delhi Durbar (also known as *The Durbar at Delhi*, 1912) which was filmed in December 1911. The Kinemacolor process consisted of alternating frames of specially sensitized black-and-white film which were photographed at 32 frames per second through a rotating filter with alternating red and green areas. The film was then printed and projected through the same alternating red and green filter at the same speed. The sense of color was achieved through a combination of separate red and green alternating images and the viewer's persistence of vision.

William Friese-Greene invented another additive color system called Biocolour, which was developed by his son Claude Friese-Greene after William's death in 1921. William sued George Albert Smith, alleging that the Kinemacolor process infringed on the patents for his Bioschemes, Ltd.; as a result, Smith's patent was revoked in 1914. Both Kinemacolor and Biocolour had problems with "fringing" or "haloing" of the image, due to the separate red and green images not fully matching up.

French inventor Louis Dufay developed Dufaycolor in 1931, which was a reversal film (producing a positive image on the camera original) that used a mosaic of tiny filter elements of the primary colors between the emulsion and base of the film..

By the nature of the systems, additive color was not economical. Because of the filters used to project the films, more light was required than was typically projected onto the screen, resulting in an image that was dimmer than the average black and white image. The larger the screen, the dimmer the picture. For this, and other case-by-case reasons, additive processes for motion pictures grew out of favor about the time of the Second World War, though a variation of additive color systems are employed for all the color video and computer display systems of today.

Subtractive color

The first successful Subtractive color system began with Kodak's Kodachrome system. Using duplitized film, red and green records were exposed. By bleaching away the silver and replacing it with color dye, a color image was obtained. Kodak's first narrative film with the process was a short subject entitled *Concerning $1000* in 1916.

Kodachrome, however, did not find much use in the commercial market, and the first truly successful subtractive color process was William van Doren Kelley's Prizma, an early color process that was first introduced at the American Museum of Natural History in New York City on 8 February 1917. Prizma began in 1916 as an additive system similar to Kinemacolor. However, after 1917, Kelley reinvented the process as a subtractive one with several years of short films and travelogues, such as *Everywhere With Prizma* (1919) and *A Prizma Color Visit to Catalina* (1919) before releasing features such as the documentary *Bali the Unknown* (1921), *The Glorious Adventure* (1922), and *Venus of the South Seas* (1924).

The invention of Prizma led to a series of similarly-printed color processes. This bipack color system used two strips of film running through the camera, one recording red, and one recording blue-green light. With the black and white negatives being printed onto duplitized film, the color images were then toned red and blue, effectively creating a subtractive color print.

Leon Forrest Douglass (1869–1940), a founder of Victor Records, developed a system he called Naturalcolor, and first showed a short test film made in the process on 15 May 1917 at his home in San Rafael, California. The only feature film known to have been made in this process, *Cupid Angling* (1918) — starring Ruth Roland and with cameo appearances by Mary Pickford and Douglas Fairbanks — was filmed in the Lake Lagunitas area of Marin County, California.

After experimenting with more advanced methods of additive systems (including a camera with two apertures (one with a red filter one with green) from 1915 to 1921, Dr. Herbert Kalmus, Dr. Daniel Comstock, and mechanic W. Burton Wescott (who left the company in 1921) developed the subtractive color system for Technicolor. This system used a beam splitter in a specially modified camera to send red and green light waves to separate black-and-white film negatives. From these negatives, two prints were made on film stock with half the normal base thickness, which were toned accordingly: one red, the other green. Then they were cemented together, base-to-base, into a single strip of film. The first film using this process was *Toll of the Sea* (1922) starring Anna May Wong. Perhaps the most ambitious film made with this process was *The Black Pirate* (1926), starring and produced by Douglas Fairbanks and directed by Albert Parker. The system was refined through the incorporation of dye imbibition, which allowed for the transferring of dyes from both color matrices into a single print, thus avoiding the problems at attaching two prints back-to-back and allowing for multiple prints to be created from a single pair of matrices.

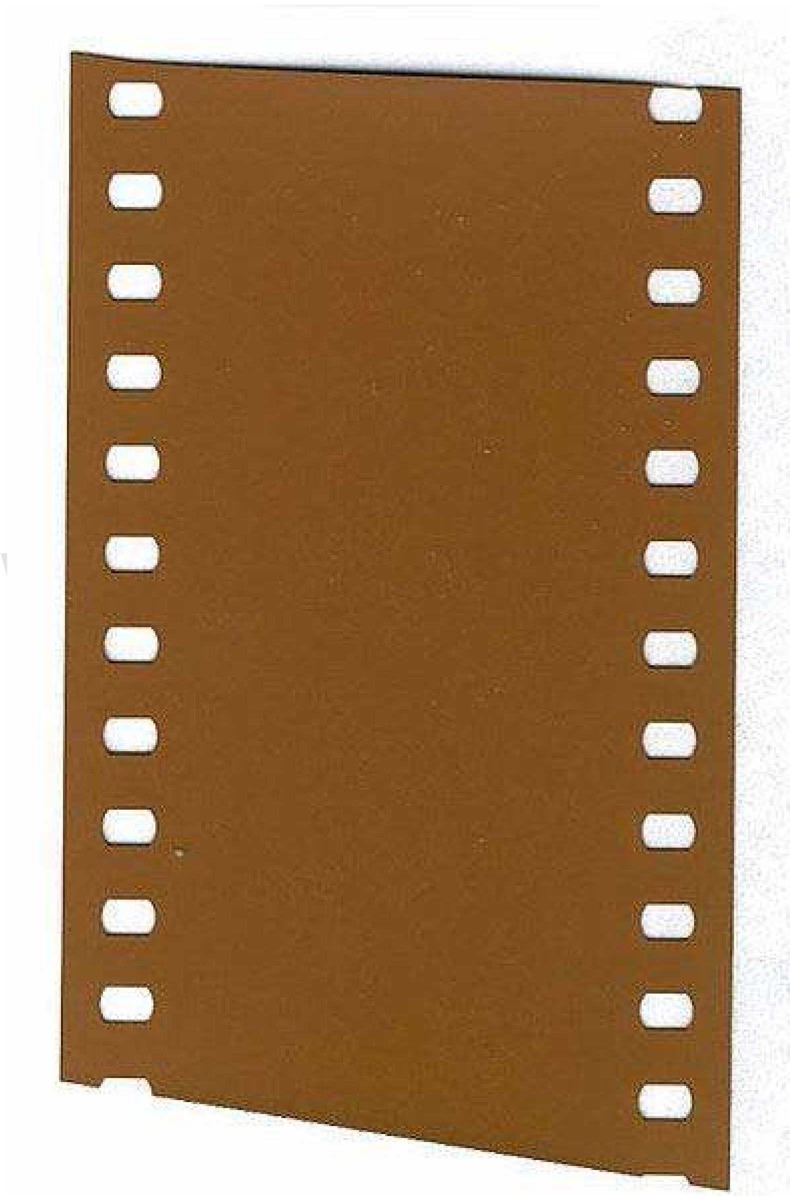
Technicolor's system was extremely popular for a number of years, but it was a very expensive process: shooting cost three times that of black and white photography and printing costs were no cheaper. By 1932, general color photography had nearly been abandoned by major studios, until Technicolor developed a new advancement to record all three primary colors. Utilizing a special dichroic beam splitter equipped with two 45-degree prisms in the form of a cube, light from the lens was deflected by the prisms and split into two paths to expose each one of three black and white negatives (one each to record the densities for red, green, and blue).

The three negatives were then printed to gelatin matrices, which also completely bleached the image, washing out the silver and leaving only the gelatin record of the image. A receiver print, consisting of a 50% density print of the black and white negative for the green record strip, and including the soundtrack, was struck and treated with dye mordants to aid in the imbibition process (this "black" layer was discontinued in the early 1940s). The matrices for each strip were coated with their complementary dye (yellow, cyan, or magenta), and then each successively brought into high-pressure contact with the receiver, which would imbibe and hold the dyes which collectively were able to render a wider spectrum of colors than the previous technologies. The first animation film with the three-color (also called three-strip) system was Walt Disney's *Flowers and Trees* (1932), the first short live-action film was *La Cucaracha* (1934), and the first feature was *Becky Sharp* (1935).

There were other subtractive processes, including Gasparcolor, a single-strip 3-color system developed in 1933 by the Hungarian chemist Dr. Bela Gaspar.

The real push for color films, and the nearly immediate changeover from black and white production to nearly all color film, was pushed forward by the prevalence of television in the early 1950s. In 1947, only 12 percent of American films were made in color. By 1954, that number rose to over 50 percent. The rise in color films was also aided by the breakup of Technicolor's near monopoly on the medium. In 1947, the United States Justice Department filed an antitrust suit against Technicolor for monopolization of color cinematography (even though rival processes such as Cinecolor and Trucolor were in general use). In 1950, a Federal court ordered Technicolor to allot a number of its three-strip cameras for use by independent studios and filmmakers. Although this certainly affected Technicolor, its real undoing was the invention of Eastmancolor that same year.

Monopack color film



A strip of undeveloped 35 mm color negative

Modern color film is based on the subtractive color system, which filters colors from white light through dyed or color sensitive layers within a single strip of film. A subtractive color (cyan, magenta, yellow) is what remains when one of the additive primary colors (red, green, blue) has been removed from the spectrum. Eastman Kodak's monopack color film incorporated three separate layers of color sensitive emulsions into one strip of film. Kodachrome was the first commercially successful application of monopack multilayer film, introduced in 1935.

Eastmancolor, introduced in 1950, was Kodak's first economical, single-strip 35 mm negative-recording system incorporated into one strip of film. This rendered three-strip color photography relatively obsolete, even though, for the first few years, Technicolor's quality control in printing produced colors that were more precise than monopack film and the dye-transfer print would maintain its color much longer than an Eastman print, which would fade over time, mostly due to poor processing and improper storage. The first commercial feature film to use Eastmancolor was the documentary *Royal Journey*, released in December 1951. Hollywood studios waited until an improved version of Eastmancolor negative came out in 1952 before using it.

Technicolor continued to offer the dye-imbibition print process for projection prints until 1975, and even briefly revived it in 1998. As an archival format, Technicolor prints are one of the most stable color print processes yet created, and prints properly cared for are estimated to retain their color for centuries. With the introduction of low-fade (LPP) films, properly stored (at 45 °F or 7 °C and 25 percent relative humidity) monopack color film is expected to last, with no fading, a comparative amount of time. Kodachrome transparency film stored at 0^{o}F (−18 °C) is predicted to last a similar length in time without noticeable picture degradation. Improperly stored monopack color film from before 1983 can incur a 30 percent image loss in as little as 25 years.

Modern manufacturers of color film for motion picture use

Motion picture film, primarily because of the rem-jet backing, requires different processing than standard C-41 process color film. The process necessary is Eastman Color Negative 2 (ECN-2), which has an initial step using an alkaline bath to remove the backing layer. There are also minor differences in the remainder of the process. If motion picture negative is run through a standard C-41 color film developer bath, the rem-jet backing will partially dissolve and destroy the integrity of the developer and, potentially, ruin the film.

There are two main companies manufacturing color film for motion picture use: Eastman Kodak and Fujifilm.

Kodak color motion picture films

In the late 1980s, Kodak introduced the T-Grain emulsion, a technological advancement in the shape and make-up of silver halide grains in their films. T-Grain is a tabular silver halide grain that allows for greater overall surface area, resulting in greater light sensitivity with a relatively small grain and a more uniform shape which results in a less overall graininess to the film. This made for sharper and more sensitive films. The T-Grain technology was first employed in Kodak's EXR line of motion picture color negative stocks. This was further refined in 1996 with the Vision line of emulsions, followed by Vision2 in the early 2000s and Vision3 in 2007.

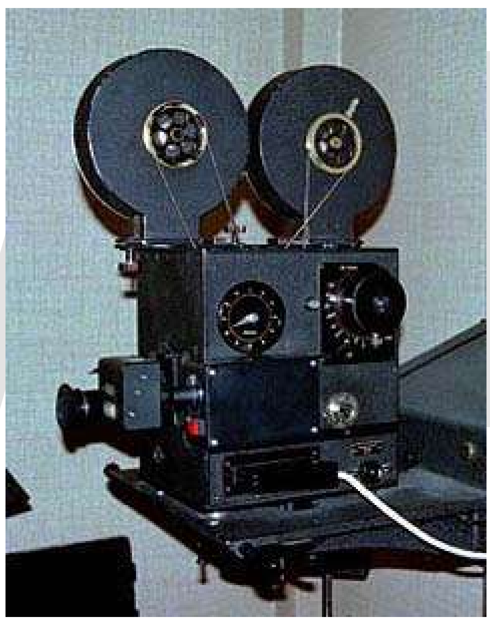
Fuji color motion picture films

Fuji films also integrate tabular grains in their SUFG (Super Unified Fine Grain) films. In their case, the SUFG grain is not only tabular, it is hexagonal and consistent in shape throughout the emulsion layers. Like the T-grain, it has a larger surface area in a smaller grain (about one-third the size of traditional grain) for the same light sensitivity. In 2005, Fuji unveiled their Eterna 500T stock, the first in a new line of advanced emulsions, with Super Nano-structure Σ Grain Technology.

Chapter- 8

Animation Camera & Computer Animation Production System

Animation camera



An animation camera manufactured by Crass, Berlin, in 1957

An **animation camera**, a type of rostrum camera, is a movie camera specially adapted for frame-by-frame shooting animation or stop motion. It consists of a camera body with lens and film magazines, a stand that allows the camera to be raised and lowered, and a table, often with both top and underneath lighting. The artwork to be photographed is placed on this table.

Since most animation is now produced digitally, new animation cameras are not widely manufactured. Image scanners, video cameras and digital SLRs have taken their place.

Examples of professional animation cameras (35 and 16 mm)

A partial list of manufacturers of animation cameras includes:

- Acme Tool and Manufacturing (USA)
- Crass (Germany)
- Neilson-Hordell (UK)
- Oxberry (USA)
- Double M Industries (USA)
- A.I.A. Productions (USA)

The Bell & Howell 2709 (Design 27, first made in 1909) is the prototype of the Acme, and the Acme is the prototype of the Oxberry. Each employs a fixed pin and "shuttle" movement mechanism for film registration and film advancement, respectively. Other names associated with Acme were Producer's Service Corporation and Photo-Sonics.

Super 8

In addition, many consumer-grade Super 8 home movie cameras made in the 1960s and 1970s had single-frame, and therefore, animation, capability. Their wide availability on the used market (along with the continued manufacture of Super 8 film) make them a viable low-cost alternative to specialized animation cameras when paired with a suitable animation stand (copy stands are often adapted to this purpose).

16 mm

The 16 mm Bolex camera is often used for amateur and semi-professional single frame filming, either using its built-in spring drive, or an attached electric single-frame motor

Computer Animation Production System

The **Computer Animation Production System (CAPS)** is a proprietary collection of software programs, scanning camera systems, servers, networked computer workstations, and custom desks developed by The Walt Disney Company together with Pixar in the late-1980s. Its purpose was to computerize the ink and paint and post-production processes of traditionally animated feature films produced by Walt Disney Animation Studios.

CAPS in film production

CAPS was the first digital ink and paint system used in animated feature films, designed to replace the expensive process of transferring animated drawings to cels using India ink or xerographic technology, and painting the reverse sides of the cels with gouache paint. Using the CAPS system, enclosed areas and lines could be easily colored in the digital computer environment using an unlimited palette. Transparent shading, blended colors and other sophisticated techniques could be extensively used that were not previously available.

The completed digital cels were composited over scanned background paintings and camera and/or pan movements were programmed into a computer exposure sheet simulating the actions of old style animation cameras. Additionally, complex multiplane shots giving a sense of depth were possible. Unlike the analog multiplane camera, the CAPS multiplane cameras were not limited by artwork size. Extensive camera movements never before seen were incorporated into the films. The final version of the sequence was composited and recorded onto film. Since the animation elements exist digitally, it was easy to integrate other types of film and video elements, including three-dimensional computer animation.

Evolution of the system

The first usage of the CAPS process was Mickey standing on Epcot's Spaceship Earth for "The Magical World of Disney" titles. The system's first feature film use was in the production of *The Little Mermaid* in 1989; however, the use of the system was limited to the farewell rainbow sequence near the end. The rest of the film used traditional painted cels. Subsequent films were made completely using CAPS; the first of these, *The Rescuers Down Under*, was the first 100% digital feature film ever produced. Subsequent films, including *Beauty and the Beast*, *Aladdin*, *The Lion King*, and *The Hunchback of Notre Dame* took more advantage of CAPS' 2D/3D integration. After *The Little Matchgirl*, the system has never been used again.

Special edition editing

For the Special Edition IMAX and DVD versions of *Beauty and the Beast*, *Aladdin*, *The Lion King*, and *Mulan*, new renders of the original elements were done and recorded to alternate master formats. In addition, *Beauty and the Beast* and *The Lion King* had newly animated sequences added to their special editions, and both of the IMAX editions and *Aladdin* had significant cleanup/restoration done on the original digital sequence elements to enhance detail, correct mistakes, and solidify clean-up animation and drawing.

Significance

In 1992, the team that developed CAPS won an Academy of Motion Picture Arts and Sciences Scientific and Engineering Award. They were:

- Randy Cartwright (Disney)
- David B. Coons (Disney)
- Lem Davis (Disney)
- Thomas Hahn (Pixar)
- James Houston (Disney)
- Mark Kimball (Disney)
- Dylan W. Kohler (Disney)
- Peter Nye (Pixar)
- Michael Shantzis (Pixar)
- David F. Wolf (Disney)
- Walt Disney Feature Animation Department

CAPS was capable of a high level of image quality using significantly slower computer systems than are available today. The final frames were rendered at a 2K digital film resolution (2048 pixels across at a 1.66 aspect ratio), and the artwork was scanned so that it always held 100% resolution in the final output, no matter how complex the camera motion in the shot.

In 2004, Disney Feature Animation management decided that audiences wanted only 3D computer animated features and closed down their traditional 2D animation department. The CAPS desks were removed and the custom automated scanning cameras were dismantled and scrapped. As of 2005, only one desk system remained (and that was only for the purpose of reading the data for the films that were made with this system).

The acquisition of Pixar by Disney in 2006—along with the corresponding influx of artists and management, including Chief Creative Officer John Lasseter—meant that the future of traditional, 2D animation at Disney was subject to change. Pixar prides itself not only on its world-class 3D skills and knowledge, but many of its artists and managers also pay deep homage to traditional, 2D animation, including Lasseter himself, who had experience as a Disney animator prior to co-founding Pixar.

Since the merger with Pixar, Disney has finished production on a new 2D animated film, *The Princess and the Frog*, released in November 2009. As most of CAPS was shut down and dismantled, and based upon now-outdated hardware and software, Disney's latest traditionally animated productions (*How to Hook Up Your Home Theater*, *The Princess and the Frog*, and the upcoming *Winnie the Pooh*) are being produced using Toon Boom Harmony computer software, which offers an updated, more cost-effective digital animation system. The Toon Boom software had been in use by the DisneyToons Studio subsidiary from 1999 onward.

Chapter- 9

Movie Camera

The **movie camera** is a type of photographic camera which takes a rapid sequence of photographs on strips of film which was very popular for private use in the last century until its successor, the video camera, replaced it. Many of these cameras today have become collectors items and there is a small but well organized group of fans of these devices who still use and maintain these cameras as hobby or a special interest, even if they went out of productions a long time ago. For professional purposes however, movie cameras are used and produced today, especially for the production of full feature movies. In contrast to a still camera, which captures a single snapshot at a time, the movie camera takes a series of images; "frame". This is accomplished through an intermittent mechanism. The frames are later played back in a movie projector at a specific speed, called the "frame rate" (number of frames per second). While viewing, a person's eyes and brain merge the separate pictures together to create the illusion of motion.

History

One of the first motion-picture film cameras, was designed by Louis Le Prince in 1888. It still exists with the National Media Museum, England. Le Prince employed paper bands and celluloïd film from John Carbutt and or Blair & Eastman in 1¾ inch width.

On June 21 1889, William Friese-Greene was issued patent no. 10131 for his 'chronophotographic' camera. It was apparently capable of taking up to ten photographs per second using perforated celluloid film. A report on the camera was published in the British *Photographic News* on February 28 1890. On 18 March, Friese-Greene sent a clipping of the story Friese-Greene gave a public demonstration in 1890 but the low frame rate combined with the device's apparent unreliability failed to make an impression.

Georges Demenÿ, employee with Etienne Jules Marey, constructed the Beater Movement in 1893. The film width is 60 mm.

Max Skladanowsky conceived his own make of camera in 1894-95, but more interesting is his “Bioscop” projector, the first duplex construction in practice. Green, part designer for Prestwich, also designed a duplex projecting machine. This 1896 wide-film projector can be seen at the South Kensington Science Museum.

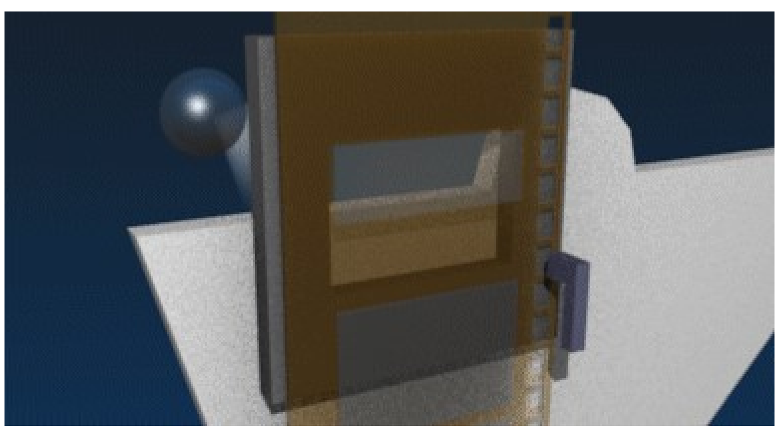
The Lumière Domitor camera was originated by Charles Moisson, chief mechanic of the Lumière works at Lyon in 1894. They shot on paper film of 35 millimeter width. In 1895 the Lumière could buy celluloïd film from New-York's Celluloid Manufacturing Co. This they covered with their own Etiquette-bleue emulsion, had it cut into strips and perforated. It is not known which recipe they used for positives.

Then an ever increasing number of cine cameras came up. The makes and brands would be: Birt Acres (1894-95), the Latham Eidoloscope by Lauste (1895), the Marvin & Casler Bioscope by Dickson (1895), Pathé frères (1896) with ratchet claws, Prestwich (1896), Newman & Guardia (1896), de Bedts, Gaumont-Démény (1896), Schneider, Schimpf, Akeley, Debrie, Bell & Howell, Leonard-Mitchell, Ertel, Ernemann, Eclair, Stachow, Universal, Institute, Wall, Lytax, and many others.

The first all-metal cine camera is the Bell & Howell Standard of 1911-12. One of the most complicated models is the Mitchell-Technicolor Beam Splitting Three-Strip Camera of 1932. With it, three colour separation originals are obtained behind a purple, a green, and a red light filter, the latter being part of one of the three different raw materials in use.

The most popular 35 mm cameras in use today are Arriflex, Moviecam (now owned by the Arri Group), and Panavision models. For very high speed filming, PhotoSonics are used.

Technical details



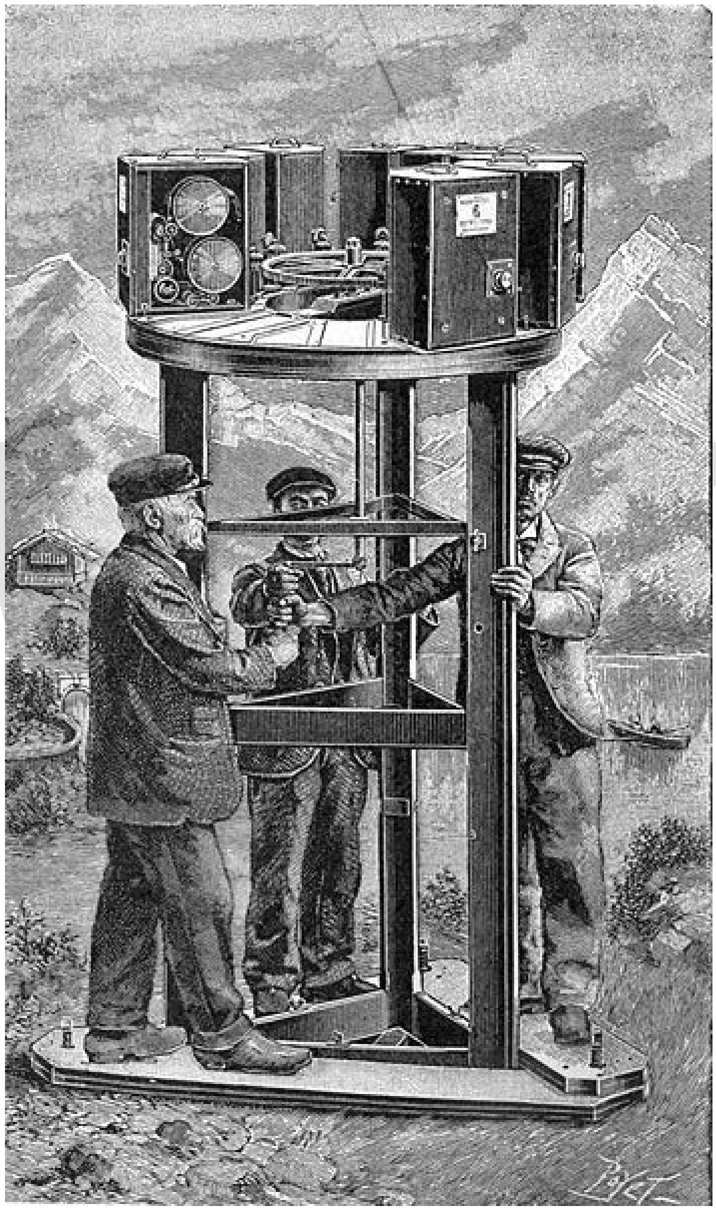
Basic operation: When the shutter inside the camera is open, the film is illuminated. When the shutter is completely covering the film gate, the film strip is being moved one frame further by one or two claws which advance the film by engaging and pulling it through the perforations.

Most of the optical and mechanical elements of a movie camera are present in the movie projector. The requirements for film tensioning, take-up, intermittent motion, loops, and rack positioning are almost identical. The camera will not have an illumination source and will maintain its film stock in a light-tight enclosure. A camera will also have exposure control via an iris aperture located on the lens. Also, there is a rotating, sometimes mirrored shutter behind the lens, which alternately passes the light from the lens to the film, or reflects it into the viewfinder. The righthand side of the camera is often referred to by camera assistants as "the dumb side" because it usually lacks indicators or readouts and access to the film threading, as well as lens markings on many lens models. More recent equipment often has done much to minimize these shortcomings, although access to the film movement block by both sides is precluded by basic motor and electronic design necessities.

A spring-wound Bolex 16 mm camera

The standardized frame rate for commercial sound film is 24 frames per second. The standard commercial (i.e., movie-theater film) width is 35 millimeters, while many other film formats exist. The standard aspect ratios are 1.66, 1.85, and 2.39 (anamorphic). NTSC video (common in North America and Japan) plays at 29.97 frame/s; PAL (common in most other countries) plays at 25 frame/s. These two television and video systems also have different resolutions and color encodings. Many of the technical difficulties involving film and video concern translation between the different formats. Video aspect ratios are 4:3 for full screen and 16:9 for widescreen.

Multiple cameras



Multiple cameras to take surround images

Multiple synchronized cameras may be used and the films then projected simultaneously, either on a single three-image screen (Cinerama) or upon multiple screens forming a complete circle, with gaps between screens through which the projectors illuminate an opposite screen. Convex and concave mirrors are used in cameras as well as mirrors.

Sound synchronization

One of continuing problems in film is synchronizing a sound recording with the film. Most film cameras do not record sound internally; instead, the sound is captured separately by a precision audio device. This is called double-system. The exceptions to this are the single-system news film cameras, which had either an optical—or later—magnetic recording head inside the camera. For optical recording, the film only had a single perforation and the area where the other set of perforations would have been was exposed to a controlled bright light that would burn a waveform image that would later regulate the passage of light and playback the sound. For magnetic recording, that same area of the single perf 16 mm film that was prestriped with a magnetic stripe. A smaller balance stripe existed between the perforations and the edge to compensate the thickness of the recording stripe to keep the film wound evenly.

Double-system cameras are generally categorized as either "sync" or "non-sync." Sync cameras use crystal-controlled motors that ensure that film is advanced through the camera at a precise speed. In addition, they're designed to be quiet enough to not hamper sound recording of the scene being shot. Non-sync or "MOS" cameras do not offer these features; any attempt to match location sound to these cameras' footage will eventually result in "sync drift", and the noise they emit typically renders location sound recording useless.

To synchronize double-system footage, the clapper board which typically starts a take is used as a reference point for the editor to match the picture to the sound (provided the scene and take are also called out so that the editor knows which picture take goes with any given sound take). It also permits scene and take numbers and other essential information to be seen on the film itself. Aaton cameras have a system called AatonCode that can "jam sync" with a timecode-based audio recorder and prints a digital timecode directly on the edge of the film itself. However, the most commonly used system at the moment is unique identifier numbers exposed on the edge of the film by the film stock manufacturer (KeyKode is the name for Kodak's system). These are then logged (usually by a computer editing system, but sometimes by hand) and recorded along with audio timecode during editing. In the case of no better alternative, a handclap can work if done clearly and properly, but often a quick tap on the microphone (provided it is in frame for this gesture) is preferred.

One of the most common uses of non-sync cameras are the spring-wound cameras used in hazardous special effects, known as "crash cams". Scenes shot with these have to be kept short, or resynchronized manually with the sound. MOS cameras are also often used for second unit work or anything involving slow or fast-motion filming.

Home movie cameras

Various German Agfa Movex Standard 8 home movie cameras

Movie cameras were available before World War II often using the 9.5 mm film format. The use of movie cameras had an upsurge in popularity in the immediate post-war period giving rise to the creation of home movies. Compared to the pre-war models, these cameras were small, light, fairly sophisticated and affordable. An extremely compact 35 mm movie camera *Kinamo* was designed by Emanuel Goldberg for amateur and semi-professional movies in 1921. A spring motor attachment was added in 1923 to allow flexible handheld filming. The Kinamo was used by Joris Ivens and other avant-garde and documentary filmmakers in the late 1920s and early 1930s.

While a basic model might have a single fixed aperture/focus lens, a better version might have three or four lenses of differing apertures and focal lengths on a rotating turret. A good quality camera might come with a variety of interchangeable, focusable lenses or possibly a single zoom lens. The viewfinder was normally a parallel sight within or on top of the camera body. In the 1950s and for much of the 1960s these cameras were powered by clockwork motors, again with variations of quality. A simple mechanism might only power the camera for some 30 seconds, while a geared drive camera might work for as long as 75 - 90 seconds (at standard speeds). Even today there is a market among collectors for these types of camera, as the engineering and materials were of a very high standard and no battery is required. While film stock and the ability to process it exists, these cameras can still be used.

The common film used for these cameras was termed Standard 8, which was a strip of 16 millimetre wide film which was only exposed down one half during shooting. The film had twice the number of perforations as film for 16 mm cameras and so the frames were half as high and half as wide as 16 mm frames. The film was removed and placed back in the camera to expose the frames on the other side once the first half had been exposed. Once the film was developed it was sliced down the middle and the ends attached, giving 50-foot (15 m) of Standard 8 film from a spool of 25-foot (7.6 m) of 16 mm film. 16 mm cameras, mechanically similar to the smaller format models, were also used in home movie making but were more usually the tools of semi professional film and news film makers.

In the 1960s a new film format, Super8, coincided with the advent of battery operated electric movie cameras. The new film, with a larger frame print on the same width of film stock, came in a cassette which simplified changeover and developing. Another advantage of the new system is that they had the capacity to record sound, albeit of indifferent quality. Camera bodies, and sometimes lenses, were increasingly made in plastic rather than the metals of the earlier types. As the costs of mass production came down, so did the price and these cameras became very popular. This type of format and camera was more quickly superseded for amateurs by the advent of video cameras, although some professionals continued to make use of its visual characteristics alongside larger format film and video cameras.