

MOTION PICTURES

Editor's note: This month we continue a series of reprints from the IEEE Global History Network's STARS articles. STARS is an online compendium of invited, peer-reviewed articles on the history of major developments in electrical and computer science and technology. Some light editing has been done, along with the addition of a few illustrations, to make the article more suitable for a journal publication.¹

One of the most influential technologies of the past 100 years has been motion pictures. A photographic technique for capturing action became a new medium, a significant part of the economy, and a dominant part of popular culture. A long series of technical advances created the medium and allowed it to grow to express the visions of filmmakers and to provide entertainment for most of the world's population.

I. INVENTING A MEDIUM

A precursor to motion pictures was the Zoetrope. Invented in 1834, it gave the impression of continuous motion when the viewer watched a rapidly changing series of still images. In 1888, Thomas Edison filed a patent caveat for the Kinetoscope, which, he wrote, would do "for the Eye what the phonograph does for the Ear." Edison and his associate W. Laurie Dickson built a practical camera in 1890. They used, as a medium, celluloid film,



Fig. 1. Thomas Edison and George Eastman with celluloid film.
(Photo reproduced courtesy of the Kodak company.)

Since movies began more than 100 years ago, continual technological innovation has improved this entertainment medium and art form, all the while expanding its expressive possibilities.

which George Eastman, founder of the Eastman Kodak company, had invented the year before (Fig. 1). In 1892, Edison and Dickson built a practical viewing device. One looked through a viewer at the top of a box-like cabinet to see the backlit film. In 1894, a Kinetoscope parlor opened in New York City. It cost a penny to see a motion picture sequence lasting about a minute.

Soon Kinetoscope parlors opened elsewhere. In 1895, in Paris, the brothers Auguste and Louis Lumière (Fig. 2), who had independently developed a movie camera, demonstrated a better way of viewing a motion picture: instead of a single viewer looking into a box, a group of people viewed the images projected onto a screen. In the United States, Edison purchased rights to a movie projector, renamed it the Vitascope, and demonstrated it in New York City in

¹Please refer to the STARS website for additional information and to view the full article: http://www.ieeeahn.org/wiki/index.php/STARS:Motion_Pictures.

Timeline

1834	Invention of the Zoetrope
1888	Patent caveat by Thomas Edison for the Kinetoscope
1890	Construction of a practical movie camera by Thomas Edison and W. Laurie Dickson
1892	Construction of the Kinetoscope, for viewing motion pictures, by Edison and Dickson
1894	Opening of a Kinetoscope parlor in New York City
1895	Demonstration of film projection by Auguste and Louis Lumière in Paris
1903	Release of <i>The Great Train Robbery</i> , a movie that tells a story
1923	Demonstration by Lee De Forest of a sound-on-film process
1927	Successful showing of the sound movie <i>The Jazz Singer</i>
1935	Release of the first full-length color film shot in three-strip Technicolor, <i>Becky Sharp</i>
1952	Release of the 3-D movie <i>Bwana Devil</i>
1953	Introduction of the wide-screen technology CinemaScope with <i>The Robe</i>
1970	Introduction of IMAX films, projected on a much larger screen
1982	Use of computer animation in the movie <i>Tron</i>
1995	Release of the first full-length movie created entirely on a computer, <i>Toy Story</i>

1896 (Fig. 3). A crucial invention, which permitted films longer than a few minutes, came in 1895 with the Latham loop, a slack-forming loop in the film's path before it passed by the shutter of a camera or a projector.

In the years around 1900, the basic technology of camera and projector was developed and refined. By about 1910, 35-mm film, used by Edison, became the international standard. Because the photographic film at that time required high illumination, the electric spotlight, introduced in 1904 for theaters, became important in movie making, and in 1919, a much more intense carbon-arc lamp, the klieg light, began to be used. Most filming, though, continued to use natural lighting.

Motion pictures gained popularity rapidly. Though there had been many earlier storytelling films, Edwin S. Porter's 12-min-long *The Great Train Robbery*, released in 1903, attracted much attention for its narrative style. In about 1905, nickelodeons, where film was projected on a screen, began appearing in cities. These were typically long, narrow rooms that could seat a hundred people or so. In the

United States in 1910, there were about 10 000 nickelodeons serving some 20 million viewers per week. Films moved into theaters, where they were often part of a larger entertainment program, which typically included vaudeville acts. Movies were all short, usually one-reelers, that is, up to about 15 minutes in duration. The movie house almost always provided live musical accompaniment.

Around 1910, especially in Europe, there was a move toward so-called feature films, lasting an hour or more. In the United States, D. W. Griffith's 1915 *Birth of a Nation* exemplified this move. Also in this decade, Hollywood emerged as a center of movie making. Film companies gravitated there for its climate, cheap land, and lack of labor unions. In the era of silent movies it was relatively easy to export films to other countries, and the U.S. movie industry set up distribution offices overseas. At the end of the decade, it was the fifth largest industry in the United States, where there were some 20 000 movie houses. In Europe, quite a few countries, among them France, England, Germany, Denmark, and Sweden, very early established strong national

film industries, and France had the most influential film industry until World War I. The war, however, hindered European film production drastically, and Hollywood gradually established worldwide dominance.

II. TALKING PICTURES AND COLOR MOVIES

A momentous technical advance was the development of sound movies (Fig. 4). In 1923, Lee De Forest demonstrated a sound-on-film process, in which the sound was recorded optically on the film strip. In making the film, the amplitude variations of the sound were captured as variations in gray level on the film strip. In playback, a light shining through the soundtrack onto a photocell created an electrical signal sent to a loudspeaker. Hollywood, however, showed little interest, in part because there had already been many failed attempts at synchronizing sound with motion pictures. In 1924, Western Electric demonstrated a sound-on-disk system, which used the same electric motor to drive the projector and the phonograph so that it was easier to maintain synchronization.



Fig. 2. Auguste and Louis Lumière.

The Warner Brothers studio took up the Western Electric system, using it in 1926 with *Don Juan* (in which there was no talking, but with music synchronized to the action) and in 1927 with *The Jazz Singer* (which had several dialog sequences in addition to synchronized music). Both were successful, *The Jazz Singer* so much so that other studios rushed to make sound movies. The technology that won out, however, was the sound-on-film system, thanks especially to work by General Electric and by the German developers of the so-called Tri-Ergon system. Because the conversion to sound movies was ex-

pensive and because sound movies were more expensive to produce, the major Hollywood studios increased their market dominance within the United States. Sound movies helped competitors overseas, however, as it tended to segment the market by language.

Before the 1920s, movies were often shot at 16 frames a second. At this rate, flickering of the image was noticeable, hence the name “flicks” for movies. Frame rates increased in the 1920s, but there was much variability until sound movies finally brought standardization of the 24-per-second frame rate.

Movies appealed to all social classes, and the movie business boomed in the 1930s. In 1939, the average weekly movie attendance in the United States was 85 million, equal to two-thirds of the nation’s population. Because they were doing so well financially, the studios were disinclined to invest in new technologies, but the decade nevertheless saw several significant advances. One was deep-focus cinematography. Much more intense lighting, notably from powerful carbon-arc lamps, allowed cinematographers to decrease aperture, thus increasing depth of field. Contributing also were more sensitive film stocks and new lens coatings that permitted more light to pass through the lens. Another technical advance was dubbing, in which the original soundtrack was replaced with one in a different language. Most audiences much preferred this to the use of subtitles. Dubbing began in 1932 and helped the Hollywood studios regain overseas audiences they had lost with the coming of sound movies.

A third technical advance of the 1930s was greater use of color, which was pioneered by Disney cartoons of the early 1930s, such as *Flowers and Trees* and *Three Little Pigs*. Color was highly successful in the full-length animated film *Snow White and the Seven Dwarfs* in 1937 and in the feature films *Becky Sharp* in 1935 and *Gone with the Wind* in 1939. These films were shot in so-called three-strip Technicolor, a system in which action was captured on three strips of film simultaneously. A camera, using a beam splitter and color filters, recorded three regions of the spectrum, red, green, and blue, on separate filmstrips; and in the laboratory, a single full-color filmstrip was created from these three. Because of cost, however, color movies did not become standard until the late 1960s.

In the United States, as in many other countries, motion picture attendance climbed during World War II, and it reached an all-time peak shortly



Fig. 3. Edison's Greatest Marvel: The Vitascope.

after the war. There was better sound recording and mixing, and in 1940, Disney's *Fantasia* introduced stereo sound for movies. The blue-screen process, used to superimpose a person's image on a separate background, was first used in the 1940 movie *Thief of Bagdad*. In the late 1940s, filming on location became more common, facilitated by portable power units developed for that purpose. In 1948, the so-called "Paramount decision," which the movie industry unsuccessfully appealed all the way to the U.S. Supreme Court, ended the vertical integration of the film business. The studios were now compelled to separate cinema operation from production and distribution. Also, this ruling ended restrictive contracts with actors.

In Europe during the interwar years, the film industries in most countries thrived. Indeed, French and British cinema achieved international success in the 1930s, while in the same period the totalitarian regimes of Germany, Italy, and the Soviet Union made much use of cinema as a propaganda medium. In Japan, for cultural and financial reasons, silent movies continued to be made through the 1930s.

III. CINEMASCOPE AND DRIVE-IN THEATERS

In the United States, weekly movie attendance declined from 90 million in 1948 to 51 million in 1952, partly as a result of television and partly as a result of the move of many people to the suburbs. Thousands of cinemas closed in the 1950s and 1960s. The movie industry sought to regain customers by technological improvements such as widescreen formats, stereo sound, and 3-D images. From 1952 through 1954, several widescreen formats were introduced, notably Cinerama, which required three synchronized projectors, and CinemaScope and Panavision, both of which used a single projector. CinemaScope, which premiered with the 1953 movie *The Robe*, used anamorphic projection, which stretches an image horizontally. This allowed CinemaScope to use 35-mm film, which was less

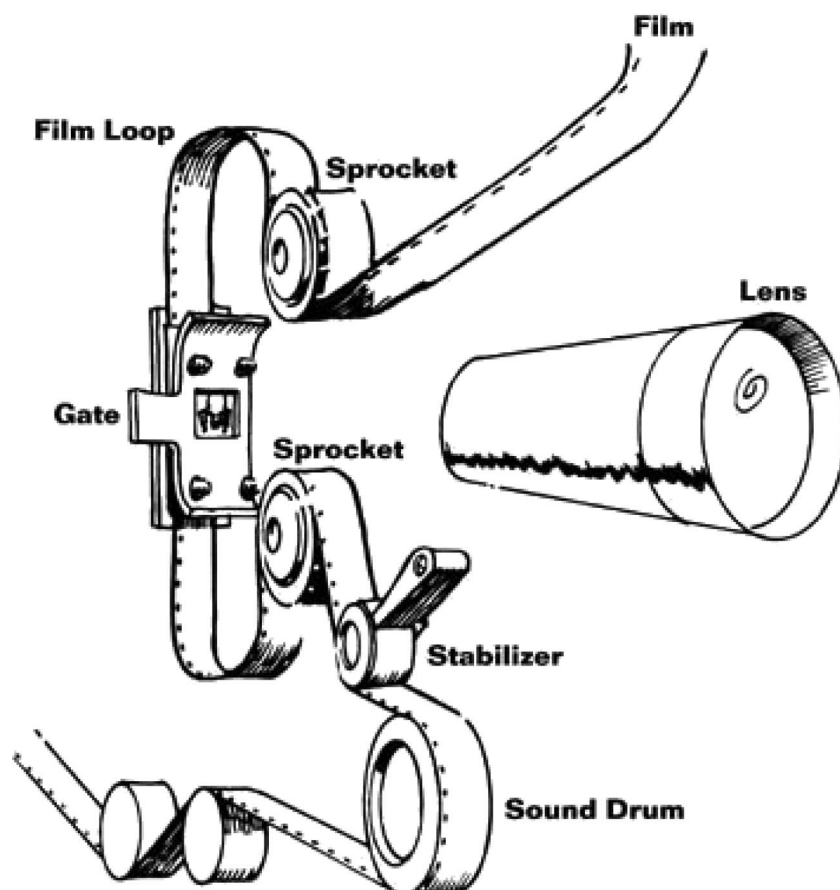


Fig. 4. Diagram of a projector for sound movies.

expensive than wider film, and it gave better image quality than widescreen systems that cropped the frame.

Stereo, which gave a spatial distribution of sound using left and right loudspeakers driven by different soundtracks, became common, and some of the largest cinemas implemented sound systems with more than two tracks. Magnetic sound recording, newly available around 1950, facilitated movie production. Several types of 3-D projection had been demonstrated in the 1920s and 1930s, but it was the 1952 release of *Bwana Devil* that made the technique well known and started a brief 3-D craze.

Also in this decade, the number of color movies increased. The introduction in 1950 of Eastmancolor, a single-strip film which could be used in a standard 35-mm camera, made it much less expensive to make a color movie. (Technicolor required a bulky camera, and the company demanded that Technicolor staff be on set.) In the 1950s, in the United States, but not in Europe, drive-in theaters became common. The first drive-in movie theater had opened in 1933, but there were very few drive-ins before 1946. The number in the United States grew from 800 in 1948 to 6000 in 1961, which was the high point for the business, and in 1956 more people went to drive-ins than to “hardtop” cinemas. The drive-in movie business, however, underwent a great decline in the late 1970s and early 1980s, in part because more people had color TVs at home and because real-estate prices and a limited season made it much more expensive to operate a drive-in than a traditional movie house.

In the 1960s, greater use of color and greater permissiveness in movie making were industry responses to the lure of television. In the United States, concern about the increase in sex, violence, and profanity in movies, however, led to the adoption of movie ratings in 1968. Lightweight cameras with portable synchronous sound equipment made it much easier to film on location, and faster film stocks

made it easier to film indoors and at night. Development of new zoom lenses in the late 1950s led to extensive use of zoom in the 1960s.

In the middle decades of the century, Japan had the most productive film industry outside the United States until India overtook it in the 1970s. Japanese movies remained highly influential, especially in other Asian countries. India had a thriving film industry already in the 1920s, centered, then and since, on Bombay (Mumbai). In the last decades of the 20th century, Indian cinema grew to be second only to Hollywood in earnings.

IV. IMAX, VIDEOCASSETTES, AND COMPUTER-GENERATED IMAGERY

In 1970, a new format, IMAX, offered a screen size ten times that of conventional films. Because of construction costs, the number of IMAX theaters grew slowly, and production costs limited the number of IMAX movies. Dolby noise reduction, which reduced tape hiss and other noise, was introduced to movies with *A Clockwork Orange* in 1971, and multitrack sound finally became established in cinemas with the arrival of Dolby four-channel sound in 1975. The sound system attracted much notice with *Star Wars* in 1977, and this movie also made use of new special effects, notably “motion control,” which was computerized control of both camera and model.

Toward the end of the 1970s, movies began to be sold on videocassette and on video disk. There were two competing videocassette formats: Betamax, introduced by Sony, and VHS, introduced by the rival Japanese electronics company JVC, and there were three competing videodisk formats, Philips’s LaserVision, RCA’s SelectaVision, and JVC’s VHD. Videodisks did not become popular, but videocassettes did, with the VHS format outcompeting the Betamax format. Already in the mid 1980s rentals and sales of videos were a huge business, greatly increasing home consumption

of movies. Indeed, in 1987 in the United States, video rentals surpassed ticket sales as the leading revenue source for the movie industry.

In the later decades of the 20th century, Hollywood retained a dominating position, as its films were marketed worldwide and exhibited in new ways, including television, videos, and DVDs. Other internationally prominent centers of filmmaking were Bombay (Mumbai), Hong Kong, and Paris. In the 1980s, many major studios became part of media and consumer electronics conglomerates. Warner merged with Time, News Corporation acquired Fox, Sony acquired Columbia and Tri-Star, and Matsushita acquired MCA-Universal.

Characteristic of the 1980s were multiplex cinemas. Though the first multiplexes appeared in the 1960s, it was in the 1980s that they became common. The major studios emphasized action movies, and they directed marketing more than ever to teens and young adults. At the same time, the number of independent films increased dramatically. The new and large video market made it much easier for independent filmmakers to obtain financing for their films and to distribute them.

Computers became important in film production, especially for computer-generated imagery (CGI). Such computer animation debuted in the movie *Tron*, released by Walt Disney Pictures in 1982. By the end of the decade CGI was lowering the cost of producing certain effects and making possible images that could hardly be created in other ways. The Turner Broadcasting System made use of computer technology in another way when, in 1987, it began offering colorized versions of black-and-white movies.

V. HOME-THEATER SYSTEMS AND THE MOVE TO DIGITAL

In the 1990s, viewing of movies in the home increased markedly. There were video rentals and video purchases



Fig. 5. High-definition digital camcorder. (Photo distributed under the terms of the GNU Free Documentation License.)

and, late in the decade, DVD rentals and DVD purchases. Cable and satellite TV offered movie channels and pay-for-view movies. And direct-to-video movies, bypassing theaters altogether, became an important business. People acquired home-theater systems, with large screens and multiple speakers, so that the home experience approximated the cinema experience. The most obvious technological change of the decade was the arrival of DVDs and DVD players in 1997. Another obvious change was improved sound, both in cinemas and in homes. The 1992 movie *Batman Returns* pioneered Dolby Digital, a 5.1-channel digital sound

system. (The channels were left, center, right, left-rear, and right-rear, supplemented by a subwoofer channel for lowest frequencies.) A similar system became part of DVD specifications, and a principal attraction of many home theaters was a six-speaker sound system for Dolby Digital.

In the 1990s, computer-generated special effects became widespread. The first computer-generated 3-D character appeared in the 1989 movie *The Abyss*. Morphing, the computer technique of changing one image seamlessly into another image, appeared in the 1991 movie *Terminator 2*. The success of *Jurassic Park* in 1993 made clear to filmmakers the value of

CGI. The 1994 movie *Forrest Gump* combined, in several sequences, historical footage and live action, and the 1995 movie *Toy Story* was the first commercially released full-length movie created entirely on a computer. Motion capture, a technique of recording physical movements, made digital creations move realistically. The 1999 movie *The Matrix*, in the technique called “bullet time,” used computers to create seamless action from multiple stills.

Characteristic of the 1990s was the move from analog to digital with cell phones, cameras, camcorders, answering machines, and other consumer electronics. This move gradually occurred with movies, in production, in distribution, and in cinemas. The 2002 movie *Star Wars Episode II: Attack of the Clones* was shot digitally, and the 2008 *Slumdog Millionaire*, filmed in India, was the first digitally shot movie to win the Academy Award for best cinematography. Cinemas acquired digital projectors, and movies began to be distributed through the Internet and by satellite networks. Digital camcorders, which made it easier and less expensive to make movies, were a boon to independent filmmakers (Fig. 5).

Motion pictures began as an electromechanical technology in the 1890s. In the course of the 20th century, a wide range of technological advances continually reshaped the medium. Electronic and computer techniques became more and more important, and motion pictures entered the 21st century moving from the analog to the digital realm. ■

FREDERIK NEBEKER

ABOUT THE AUTHOR

Frederik Nebeker received the Ph.D. degree in history of science and technology from Princeton University, Princeton, NJ.

He worked at the American Philosophical Society and at the Center for History of Physics before moving in 1990 to the IEEE History Center at Rutgers University, New Brunswick, NJ, USA, where he retired as Senior Research Historian in 2011. He is author, coauthor, or editor of ten books, most recently *Dawn of the Electronic Age: Electrical Technologies in the Shaping of the Modern World, 1914 to 1945* (New York, NY, USA: Wiley, 2009).