Film and the Future of Imaging

By J. F. Dupont

The opportunities for high-quality motion imaging are growing with the addition of new distribution channels like digital television (DTV), high-definition television (HDTV), games, and the Internet. A major challenge is dealing with many different and incompatible formats. Film has a major role in image origination because of its very high performance in latitude, color range, and resolution, which exceeds that of any foreseeable distribution format. Film is hardware and software-independent and thus perfect for archival presentation. Despite recent advances, electronic projection is still far behind in quality and cost; it is cheaper to print a 35mm theatrical release than to transmit it electronically. The trend is to improve the theatrical experience with larger formats, screens, and frame rates. To support the demand for high quality, Kodak continues to invent new ways of using electronic and digital technologies to push film farther. This merging has already begun; let us enjoy it.

Our subject is the future of imaging, and as the press keeps telling us, it has already begun. We have all heard the news: Soon we will be choosing from hundreds of television channels, movies on demand, interactive multimedia, virtual reality. Soon we will be watching DTV, widescreen television, and HDTV.

It is all a bit overwhelming and confusing. To make some sense of it, we will begin by looking at the future of television imaging and the part film will play. Then, we will take a glance at the unique film capabilities. Finally, we will conclude with a review of some of Kodak's contributions to the future of motion imaging.

Film and the Future

The future of film seems to be about two things: First, new ways of using, manipulating, transmitting, and viewing images, including television and movies; interactive media, such as video games; CD-ROMs; and the Internet. For producers of moving images, these add up to a wealth of new opportunities; for audiences, they mean many new program choices.

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Second, the future is about improving the quality of the images we watch, especially in the home. That is where digital, widescreen, high-definition television comes in—to bring us sharper, wider, and more enjoyable viewing experiences.

That is the positive side, the promise of television's future. But there are also potential problems, or at least questions that remain unanswered. As of now, we still do not know how, or in what format, high-quality digital images will be broadcast to our homes. The worldwide television broadcast industry has been talking HDTV for about two decades, but not until recently did it decide the future was in digital formats.

While Europe waits to see, the U.S. Federal Communications Commission (FCC) made some important decisions in April 1997 and ignored others. It announced that by 2006 all television broadcasting in the U.S. will be digital. In that year, DTV will make current broadcasting technology and television sets obsolete.

However, there is still some doubt that this will really happen. If enough consumers do not own digital televisions or equipment that enables their sets to receive digital signals, the date could be delayed.

More important, the FCC gave up the struggle for technical standards. A standard for DTV's frame rate, scan rate, aspect ratio, number of lines of resolution, etc., was not decided upon. Instead, the FCC approved a variety of proposed formats and said the market should decide which ones would prevail. That means digital television can be high definition (HD) or standard definition (SD), widescreen or standard screen. Broadcasters do want to offer better television images, so we can assume they will be available in one or more formats in the near future.

On the other hand, we do not know what kind of cameras, recorders, and broadcast systems will be used, and there are conflicting approaches. For example, a coalition of computer companies favors progressive scan image transmission systems, while most broadcasters are split between interlaced and progressive formats.

Various technical and financial motives are driving this conflict, but the fact that computer companies are involved at all tells us something else about the future of television imaging. It will be an era of merging technologies, merging markets, and merging companies. We may see computers that act like televisions, televisions that act like computers, and telephone companies using their cables and satellites to connect us to both computer networks and television programming.

Film's Role and Capabilities

Amid all these electronic possibilities and puzzles, what is the role for film? Many creators of new programs will choose motion picture film because it has what the future will demand: highest image quality and worldwide image compatibility. The image it carries is compatible with, and independent of, any particular analog or digital television system. For them, the question becomes: "Which photographic stock and which format?"

Thirty-five-millimeter color negative film format is used largely to capture primetime television programs, movies, and commercials. Although 16mm film formats are also used in television productions, the fact remains that 35mm is the preferred film origination format. The results of everyone's efforts and investments are the images displayed on the television screen. Motion picture film is a safe origination medium for today and tomorrow.

Let us look at this a bit more closely. First, film quality—what people call the film look. It is what distinguishes film images from electronic images, and it comes from how film captures images. Film uses randomly distributed solid-state, silver halide imaging sensors. Silver halide crystals are exposed and react with developer to form metallic silver. This development is the equivalent of an amplification of the signal. A few photons captured by a crystal are transformed into thousands of metallic silver atoms. The process continues, adding a number of factors. Actual dyes store and reproduce the scene's shape and form, color and luminance.

The science that helps us measure how photographic emulsions respond to exposure and processing is called sensitometry. A sensitometric curve plots the density of the film versus exposure. Both axes use a logarithmic scale to better represent the relative importance of low and high exposures.

To extend its capability of capturing varying light levels, film uses multiple layers with different sized silver halide crystals. This is like having three sensors of staggered ranges, perfectly overlapping, resulting in a very broad exposure latitude. Film can capture everything from the brightest highlights to the deepest shadows and have both in the same shot, and within the shadows and highlights, it is able to resolve subtle tonal changes. To represent this wide dynamic range, 12 to 14 bits would be needed.

Silver halide emulsions are coated on film in multiple layers to extend the exposure latitude. In a color film, this pack is repeated three times, once for each of the primary colors. Perfect color registration is built in. Due to its wide dynamic range and wide latitude, film can display a wide spectrum of colors and an extensive range of subtle tones, producing trillions of colors.

The silver halide emulsions coated on film provide a continuous record of a scene: they respond like our eyes do. It is an analog record avoiding any of the artifacts associated with digitization. There is no aliasing because there is no sampling; charge-coupled devices (CCDs), used in electronic imaging capture, sample the scene in pixel form. There is no contouring or color banding because there is no quantization. Digital processing and storage of electronic images suffer from quantization at low bit depth, and the dithering or noise shaping used to prevent it is equivalent to what film grain does, but film grain does it at a much finer scale.

There is also the issue of resolution. Thirty-five-millimeter film captures six times the resolution of HDTV. The frequency response of a camera film, its modulation transfer function (MTF), shows that there is still detail to be obtained when scanning it at 4000 pixels per line and 3000 lines per frame. This is true even with the fastest film speed. Just compare the relative frame size of 35mm film and CCDs used in HDTV cameras.

So anything shot on film already has more than enough quality and resolution, that is, more than enough visual information, to meet the needs of any advanced television system, including digital high-definition and future delivery formats. For this reason, feature films, especially widescreen ones, and television programs produced on film, will be important to future HDTV programming. Alternatively, programs which are converted from current video formats, such as NTSC or PAL, cannot deliver the improved picture quality future systems will demand. The visual information simply isn't there.

The other demand the future will make is image compatibility. Because there is so much uncertainty about DTV and no agreement on formats and standards, it makes sense to create programming in a medium that is already a worldwide standard: film. Of course, film can be easily converted to any current or future electronic format, so no matter how the technical questions get solved, film programs will become DTV programs. That is why we say film is future proof.

Another reason film is considered future proof is its archival capabilities. Motion picture film has proven to be an excellent storage medium for preserving our visual heritage. Films made decades ago still provide entertainment and enlightenment for today's audiences, while much of the programming recorded on videotape has been lost forever.

Life expectancy of properly stored film can be 50 to 100 years while that of magnetic videotape is 10 to 20 years at best. Film archives are a significant source of revenue to the motion picture and television industry. The film vault often holds a studio's most valuable asset.

Storage conditions play an important role in extending the life expectancy of a film. The effects of excessive storage temperature, high humidity, and gaseous contaminants on film are well documented. The vinegar syndrome, due to deacetylation of cellulose triacetate film support in confined storage conditions, has been extensively discussed in the literature. Kodak has conducted research into the use of molecular sieve desiccant as a means for continuously removing the by-products generated by film kept in confined storage. Molecular sieves absorb not only moisture, but acids, oxidants, and solvents released by the film during storage, thus inhibiting the vinegar syndrome.

Future-proofness has always been a problem for electronic imaging because it is hardware dependent. Every major advance requires buying expensive new equipment, from analog recorders to digital recorders, tube cameras to CCD cameras, and so on. It is wise to be wary of investing in electronic production equipment that can become obsolete if a different standard is adopted or new improvements are developed.

With film, on the other hand, improvements are built into the film itself. There is no need to buy new hardware to enjoy the latest advances. Of course motion picture cameras have also advanced over the years, but anyone with a decent 35mm movie camera, even the one that shot *Citizen*

Kane in black and white more than 50 years ago, has already made all the equipment investment ever needed to shoot HD programming.

This theory also holds true for cinematographers who use 16mm cameras. An older Arri or Aaton 16mm camera can easily be upgraded to Super 16, allowing it to be HDTV ready. Granted, there is a small amount of investment for the upgrade, but considering that the camera could be around 25 years old, spending a few thousand dollars is not too much to ask, and the results are a world-recognized HD capture device.

We should also consider the practical advantages of using film, such as its remarkable flexibility. Filmmakers can select from a variety of film stocks to find the one that fits their exact needs. Film can be shot at any frame rate, in any aspect ratio, with any lens, in any motion picture camera. Flexibility in frame rate and aspect ratio is not available in electronic cameras.

With film-originated images, the telecine has a second stage of creativity. During telecine transfer, the image can be manipulated by stretching, squeezing, and zooming, color grade, and pan and scan to create all sorts of effects with no loss of image quality. If you tried the same thing with standard video images, they would fall apart; they do not have enough visual information to handle this kind of manipulation. So now, more than ever, the industry sees film as the medium of choice for originating images.

Improvements in Progress

In an effort to advance the art and technology of motion imaging. Kodak is concentrating on two areas: improving the already unsurpassed image quality of film and finding new ways to integrate the technologies of film and electronics.

Turning first to film, it is important to remember that film is not a static, unchanging technology. Today's film is vastly superior to that of two decades ago. During the 20 years since HDTV was introduced, film has enjoyed steady improvement, while HDTV has still not found its way into our homes.

In the late 1980s, Kodak scientists literally reinvented film. Changing the shape of the silver halide emulsion led to revolutionary breakthroughs in film speed, sharpness, and grain, in other words, in image quality. Those breakthroughs became the basis of the family of Eastman EXR films.

In 1996, further improvements in emulsion technology and even sharper, finer grained films resulted in Kodak Vision Films. Today, Vision images transferred to HDTV produce the highest quality television pictures ever made—not the best television pictures from film but the best television pictures.

Film will continue to advance as rapidly and dramatically as any other imaging technology. What will also advance is the merging of technologies: finding new ways to combine their specific strengths. Kodak is integrating film and electronics in several ways.

A simple example is the Keykode edge numbering system, a barcode on the edge of the film that contains frame indexing information. It automatically relates film frame numbers to video time code numbers, so that electronic offline editing systems can be used for film programs. More and more television programs and even feature films are using these editing systems and Keykode numbers makes it practical.

A more complex example is the Philips Spirit DataCine, a high-quality telecine, which uses a proprietary Kodak CCD linear array imaging head. With film having a wider dynamic range than any video system, it is critical to have the very best telecine to transfer the information from film to the video mastering format. Kodak and Philips entered a joint development agreement to combine two great technologies. The Spirit DataCine converts 16mm, Super 16, and 35mm film formats to all of the video formats that are being debated around the world today, including 720p.

Conclusion

This is our look at the future of television imaging and the role film and Kodak will play. We have stated that the future will be about new kinds of images and new levels of image quality. We noted that it would also involve a merging of technologies. This last point may be the most important.

We believe no single technology can provide all the creative needs of the industry. Film needs the ability of electronics to process and manipulate images, to create visions never seen before, and electronics needs the inherent image quality of film to make those visions as powerful as possible. It should be quite a future, and, as we said at the start, it has already begun. We look forward to enjoying it with you.

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