Electronic Image Acquisition Progress Report

By Mark Schubin

Electronic image acquisition spans a broad range of product categories and functions with much overlap. Challenges are being met in the mechanical, optical, opto-electronic, storage, and digital-processing domains that were once considered exclusive to others of those domains. Boundaries between consumer, broadcast, and cinematographic acquisition equipment are disappearing. Stereoscopic 3D is shaping many technological developments, including at least four types of image processing not associated with two-dimensional imagery.

The ARRI Alexa cameras, with ALEV III CMOS image sensors, are typical of the sort of subjects that would normally appear in an acquisition-technology progress report. The sensors, in this age of widescreen imagery, are the size and shape of a 4:3-aspect-ratio (4:3 AR) Super-35 film frame. The cameras, therefore, can use standard PL-mount anamorphic lenses for 2.4:1 AR cinematic images. A version with optical viewfinder seems appropriate to such digital-cinematography use.

Another version, with electronic viewfinder, however, seems more appropriate to high-definition (HD) video shooting, and the camera can capture 2880 x 1620 16:9 AR images without anamorphic optics. It is also priced well within the range of recent HD broadcast cameras. Today's range of HD broadcast-camera prices is much broader, however, especially at the low end.

New mobile telephones, such as the Apple iPhone 4, HTC Touch HD, Motorola Droid X, Nokia N8, Samsung Captivate, and Sony Ericsson Vivaz, include HD cameras. As this is being written, Aiptek's AHD-1 consumer HD camcorder is being sold new by its manufacturer for a retail price below $80.

Of course, there is a broad range of quality as well as a broad range of pricing in acquisition equipment, but recent technological developments affect that quality in ways not necessarily explained by price. Consider, for example, dynamic range.

ARRI specifies "13.5 stops of latitude" for the Alexa cameras, thanks to their "dual-gain architecture" used for reading information from the ALEV III image sensor. Lux Media Plan, however, using Thomson's Xensium sensor in the HD 1200 camera, specifies 120 dB dynamic range in high-dynamic-range mode, which could be construed as approximately 20 stops. And Live Technologies' LiveLens adaptor is said to provide an additional 4 to 6 stops of dynamic range to any camera through the use of an "active, neutral-density spatial aperture," a high-resolution, multi-pixel, opto-electronic sensor controlling an electro-optic (liquid-crystal) light-level control.

Image stability is another acquisition characteristic that may be dealt with through multiple technologies. Owle's Bubo, for example, stabilizes images from an iPhone in part through the inertia of a heavy mount. Aerial Filmworks' CineX "urban assault" vehicle uses gyroscopic camera-mount stabilization. Steadicam Tango adds 9 ft of continuous elevation control via a jib arm to the non-motorized mechanical stabilization of previous wearable Steadicam sleds. There are also optical and digital image stabilizers, internal to lenses and cameras or available in the post-production process, but at the sacrifice of image area and, therefore (for the non-optical versions), resolution.

Sacrificing resolution is not necessarily a problem if there is plenty to spare. As noted previously, ARRI's HD-resolution specification for the Alexa is 2880 x 1620, 50% greater in either direction than 1080-line HD's 1920 x 1080. Multiplying the Alexa's 2880 x 1620 should yield 4.6656 million pixels (megapixels, or Mpels), and the full sensor's 3392 x 2200 should yield an even greater 7.4624 Mpels, but ARRI calls the sensor resolution just 3.5 Mpels. That's because, as in many modern electronic cameras, a single image sensor is used, with a spatial-mosaic filter array used to separate colors, rather than a color-separation prism feeding multiple sensors. De-mosaic-ing processing is required to create a normal color picture from such color-filtered single sensors, and low-pass filtering to reduce color aliasing reduces resolution.

Still-picture cameras typically use spatial-mosaic color filtering on single sensors. Canon's EOS 5D Mark II digital single-lens-reflex (DSLR) camera uses a sensor matching the size of a full-frame 35-mm still-picture negative, 36 x 24mm, approximately twice the area of a Super 35 movie frame. The season-finale episode of the Fox television series "House," broadcast on May 17, was shot entirely with those 5D cameras, which have HD-recording capability. The large sensors appeared to provide, as might be expected, high sensitivity, high dynamic range, and a greater ability to limit depth of field, and the camera is considerably less expensive than many HD cameras. The use of DSLRs for motion-picture shooting can require many accessories and post-production processing (for such issues as the "rolling-shutter" that can cause motion artifacts), however, and, even then, might not offer desired characteristics of some video cameras.

Nevertheless, one trend in acquisition technology is toward larger sensors, though not necessarily as large as those of the 5D (or the even-larger sensor in the Vision Research Phantom 65). At the 2010 convention of the National Association of Broadcasters (NAB), Sony announced an "affordable" version of a camcorder with a 35mm movie-frame sized sensor, and Panasonic showed a model of the AG-AF100, a camcorder using the Micro Four Thirds format used in some of its and Olympus's consumer still-image cameras with interchangeable lenses. Micro Four Thirds image sensors have a 21.6mm frame diagonal, almost twice that of the popular professional 2/3-in. format but somewhat smaller than that of APS (advanced photo system) or 35mm movie frame sizes. And, while Sony's "affordable" PL-mount interchangeable-lens camcorder might seem to come from its digital-cinematography product line, another promised large-sensor, interchangeable-lens, HD camcorder comes from Sony's Alpha series of E-mount Alpha APS still cameras, the NEX-3 and NEX-5.

In fact, no single camera serves all purposes, based on such factors as cost, size, sensitivity, control, recording, and transmission. Gigawave introduced a tiny, palm-sized wireless HD camera with 2/3-in. sensor at the 2009 International Broadcasting Convention (IBC); Fraunhofer IIS showed a similarly sized wireless HD camera at NAB 2010. Although it is not wireless, Acutelogic HK's PE-1005 is an HD camera module less than 31mm wide, complete with 10:1 zoom lens. Bradley Engineering's HD 100 adds a remote-controlled pan-and-tilt head in a package just 100mm deep. GoPro's HD Hero is a tiny, lightweight HD camcorder designed to be worn by athletes; in addition to 1080p (1080-line progressive-scan) and 720p modes, it also has a 4:3 AR 960p mode.

Immersive Media's Dodeca 2360 camera system has long been capable of capturing images 360° around and 290° vertically via its 11-camera array, but it is now capable of stitching the images together live. P&S Technik's 16 Digital SR Mag can replace a film magazine on an ARRI 16SR camera (joining the earlier Joe Dunton Company's Mitchell Digital Magazine shown at IBC in 2002). Aaton's Penelope-Δ is a similar product for that company's film cameras. ARRI introduced the HD-IVS HD video-assist camera system to be added to its film cameras; it can provide simultaneous film & HD capture.

HDAVS's HDC-680, introduced at IBC 2009, is a conventional-looking broadcast-type camcorder. It records directly to removable iVDR-format hard disk drives, iVDR-packaged solid-state memories, or both simultaneously. Sony's SRW9000PL, on the other hand, introduced at NAB 2010, records on HDCAM SR tape cassettes.

As the "PL" of that model suggests, it accepts PL-mount (ARRI-developed "positive-lock") lenses. Lenses for electronic acquisition range from high-end PL-mount cinematography types to inexpensive wide-angle and telephoto accessory add-ons for consumer camcorders and even mobile-phone cameras.

Again, as in image stabilization, technological advances are shifting quality concerns to other equipment categories. Traditionally, reduction of such lens-quality degradations as chromatic aberration required advanced lens design and the use of multiple optical elements constructed of different types of glass. Now some forms of chromatic aberration may be corrected based on look-up tables in a camera's processing section or in post- production. In the opposite direction, added "lens blur" is a recent Boris FX filter effect in the company's Continuum series. With sufficient processing power, it might someday be possible even to change the focus of an image after it was shot.

Some new lens developments are associated with stereoscopic 3D, such as matching of the optical characteristics of lens pairs and the electro-mechanics of iris, zoom, and focus control mechanisms. Stereoscopic 3D was also responsible for many other recent acquisition developments.

At NAB 2009, Astrodesign showed its SHVC-03SG (stereoscopic HD video camera), one of four models of its integrated 3D HD cameras. The concept of an integrated (one-piece) 3D camera is not new. The first 3D video transmission, in 1928, used an integrated camera, and Ikegami showed an electronic version, the LK-33, in 1989. By IBC 2009, there were not only more integrated 3D HD cameras (such as the Lux Media Plan LP1, with a minimum lens interaxial distance of just 38mm) but also four models of integrated 3D camcorders from 3D-One.

By the opening of NAB 2010, the list expanded, with—in various states of operability—a fifth camcorder model from 3D-One and others from DXG, GoPro (dual HD Hero units), Panasonic, and Sony, and even one put together by Monogram simply to demonstrate its 3D switcher. Integrated stereoscopic cameras without built-in recorders have been shown by Astrodesign, Datavideo, Fraunhofer IIS (both normal and panoramic types), Ikonoskop, IndieCam, Lux Media Plan, Minoru, Silicon Imaging, Skyline Television, 3D TV Solutions (with an eight-lens "3D-Cambox"), and Wasol, the last via a 3D lens adaptor they had also shown in previous years.

There are also literally dozens of non-integrated 3D camera-mount systems designed to utilize two separate cameras in either side-by-side or beam-splitter configurations. At this year's Digital Cinema Summit, 3ality demonstrated one of its beam-splitter rigs with all stereoscopic parameters motorized and remotely adjustable. To make side-by-side stereoscopic camera mounting easier, Sony introduced the HDC-P1 camera, narrower than the HDC-1500, on which it is based. Similarly, JVC trimmed the width of its 4K camera from 124mm to 79mm. Ikegami, on the other hand, demonstrated a side-by-side rig with full-width cameras, using relay optics to bring the lens axes closer together.

At NAB 2010, Antelope placed two Vision Research Phantom V640 cameras on a Stereotec side-by-side rig to create stereoscopic slow motion. Pace and Fujinon showed the Shadow-D, a side-by-side stereoscopic rig intended to be mounted atop the long lens of a standard long-lens 2D sports camera, with the controls linked (in a variety of selectable methods) so that a single operator can control both the 2D and 3D camera setups in a single camera location.

At CEATEC (Japan's Combined Exhibition of Advanced Technology) 2009, Sony's Technology Development Group (TDG) showed a unique 3D camera system utilizing a single lens feeding dual

240-frame/s HD cameras via relay optics. The images from the camera had been shown at the Consumer Electronics Show (CES) in 2009.

The single lens of the Sony TDG camera provides very little separation between left-eye (LE) and right-eye (RE) views, a condition referred to today as "microstereopsis." The reduced LE-RE separation eliminates ghosting, making it possible for the same display simultaneously to offer 3D to a viewer wearing glasses and 2D to a viewer without glasses. The stereoscopic-viewing sensation offered by microstereopsis, however, is reduced.

Viewfinders for most stereoscopic cameras remain 2D for a good reason. Human vision utilizes two sets of muscles. One, the "accommodation" muscles, focus the eyes' lenses at the appropriate distance to what is being viewed; the other, the "vergence" muscles, aim the eyes at what is being viewed. The two are closely tied together. There is a range of comfort within which differences between accommodation and vergence distances are acceptable; outside that range, viewers experience discomfort.

In a cinema environment, where viewers are many meters from the screen, all vergence distances at or behind the screen—as well as most in front of it—are within the zone of comfort. At home-TV viewing distances, the comfort range shrinks. At camera-viewfinder viewing distances, the comfort range is tiny and does not match what either home-TV or cinema viewers will experience.

In their 3D camcorders, 3D-One uses dual viewfinders, one for each eye, with lenses to shift the viewing distance into the comfort zone. At NAB 2010, Astrodesign showed a lenticular binocular viewfinder with a similar function.

Aside from the comfort of the camera operator, another issue associated with shooting 3D is the comfort of the ultimate viewer. On a relatively small stereoscopic viewfinder, homologous points in the two eye views might be separated by only a few millimeters, even for objects at near-infinite depth. On a home 3D TV, the same points might be separated by a couple of centimeters. The same signal's images blown up to cinema-screen size, however, might involve a greater separation, causing divergence of a viewer's eyes, an unnatural condition. The stereoscopic 3ality camera rigs, therefore, provide an indication to the stereoscopic convergence operator of the danger of divergence on a large screen.

Four types of post-camera processing have been necessitated by stereoscopic 3D. One is camera-alignment correction, dealing with elevation, interaxial displacement, and rotation. In 3D rigs in which the cameras are converged (as opposed to shooting with parallel image axes), trapezoid correction is also required so the frames of the two images will be of the same height at both sides. Another form of processing is image-parameter matching between the two views: black level, gain, gamma, color, etc. A Panasonic presentation at the Hollywood Post Alliance 2010 Tech Retreat suggests that the same sort of in-camera processing used to correct lens aberrations can be applied to these types of stereoscopic correction and matching challenges.

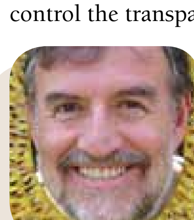
A third type of stereoscopic processing is signal formatting, getting the two images into forms appropriate for signal distribution and recording, such as LE followed sequentially by RE, LE and RE squeezed horizontally side by side, and LE over RE, with both squeezed vertically. There are many other possibilities, including mirror images and simultaneous vertical and horizontal squeezes.

The fourth form of processing associated with stereoscopic 3D is conversion from 2D to 3D. It can be as simple as forcing reddish colors toward the foreground and bluish toward the background or as complex as frame-by-frame manual positioning of every pixel. There are automatic, semi-automatic (manually assisted), and manual systems. Conversions are offered in 3D TV sets, in conversion boxes, and as services provided by post-production facilities.

Aside from those processes specific to stereoscopic motion picture sequences, all other video processing (such as editing, color grading, filtering, and duration adjustment) requires operation on both LE and RE views, nominally doubling the processing. Graphics require even more adjustment so that there will not be a conflict between the human visual "occlusion" depth cue (anything blocked by the graphic must be behind it) and the stereoscopic depth cue (which might position graphics behind what they are blocking).

Another form of processing associated with stereoscopic acquisition is the creation of virtual stereoscopic cameras. Multiple 2D camera views are processed to define a three-dimensional space into which 2D or 3D virtual cameras may be placed. Both BBC R&D and Imec have announced developments in this area.

Cameras, lenses, and mounts are not the only technologies associated with image acquisition. Another important one is lighting. LED-based lighting instruments seem to be gaining an ever-larger share, with high intensities now allowing even LED-based Fresnel spotlights, such as the Gekko Kezia and Litepanels Sola. Zylight also recently revived "active diffusion," the ability to electronically control the transparency of an optical lighting filter.



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