ÉTIENNE-GASPARD ROBERT, ROBERTSON, AS HE WAS KNOWN in Paris, perfected the “phantasmagoria” ghostly show in 1798 with an early form of the slide projector called a magic lantern, rear projection, and, literally, smoke and mirrors. We have never ended our quest to create entertainment illusions that mimic reality. Within the next three years, technology advancements will come together that will result in entertainment experiences so vivid and immersive that movies and games will completely engulf our senses. Here’s what’s in store.

FEELING IS BELIEVING

We experience entertainment primarily by what we see, hear, and feel. Huge innovations are around the corner for all three senses. Let’s look first at the one we read about the least—touch, or tactile sensing—and how we will finally get to feel like we are part of the event we are watching.

If you have been to a stock car or Formula One race or sat right up front at a hockey game, you know there is something visceral that is missing in watching the same event on TV. Is it possible to send that same thunderous feeling, along with the video and audio, and recreate that sensation for the viewer at home? You bet, and work going on in the Society of Motion Pictures and Television Engineers standards group provides a glimpse of what’s entailed.

Sensors capture the motion or vibration from a person (a driver or hockey player) or an object (a car seat) in the event. Those tactile or motion data are encoded and broadcast along with the compressed audio and video. The data being sent are amplitudes along an axis, in other words, how much movement and in which direction.

The cool part is that the system does not care what the data are or how they are recreated at home. One obvious choice is a chair that imparts the same X, Y, and Z vibration the driver feels. But the data could just as well map to the hands, chest, and seat. According to Mark Luden—chief executive officer (CEO) of Guitammer, which developed the ButtKicker brand hardware product line—“We see the market for haptic, tactile, and motion (immersive) broadcasting exploding in the next two to five years. Literally everything and everyone—from your family pet to National Football League (NFL) players—will have some kind of sensor on them transmitting all types of information, including location, motion, and force, for further use. Imagine watching the next Olympics on the ‘Immersive

“I am only satisfied if my spectators, shivering and shuddering, raise their hands or cover their eyes out of fear of ghosts and devils dashing towards them...”

—Étienne-Gaspard Robert

Entertainment and Immersive Content

What’s in store for your viewing pleasure.

By Brian Markwalter

Digital Object Identifier 10.1109/MCE.2014.2361199
Date of publication: 17 December 2014
Channel’ (whether broadcast or IPTV delivered) and being able to ski or snowboard with your favorite athlete, see what they see, and feel what they feel. Combined with a heads-up display, say, Oculus Rift, for example, and some new type of tactile or motion platform and you’ll literally be in the mountains or in the half-pipe.”

You won’t have to imagine it for very long. Silicon Valley Business Journal reports that Comcast SportsNet is embarking on a partnership with the San Jose Sharks and Guitammer to evaluate a system that transmits signals from arena sensors to in-stadium seats or at-home adapters that/vibrate fans’ seats.

BRINGING IT HOME
In the first half of the 20th century, movie theaters captured the imagination and money of people in the United States in a way to which we can scarcely relate today. In 1930, the first year for which there are reliable records, an astounding 73% of the U.S. population went to the cinema each week. After a drop in attendance during the depression, attendance bounced back to 60% during World War II, and Americans spent 23% of their recreation dollars at the movie theater. Then TV entered the scene.

As TVs showed up in more homes, movie theater attendance sank. Between 1946 and 1960, TV household penetration in the United States went from essentially zero to over 85%. In that same period, weekly movie theater attendance as a percentage of the population plunged from over 60% to a little more than 20%.

TV disrupted the movie theater business but created a hugely successful industry of its own. TV has had amazing staying power. Consumer Electronics Association (CEA) research shows that the TV is by far the most commonly owned viewing device, present in 97% of households. Further, 93% of households indicated having watched video on a TV in the previous year. No other viewing device—among laptops, desktops, smartphones, and tablets—has crossed the 50% mark.

In terms of quality and immersion, analog TV was a step backward from the resolution and widescreen presentation found in theaters. That deficit was mostly rectified with the introduction of HDTV, which brought us 1,920 × 1,080 resolution and multichannel surround sound. Today, we are on the leading edge of dramatic change in visual entertainment in three fields: ultra-HDTV, digital actors, and virtual reality (VR).

PICTURE THIS
Despite the slight downturn in U.S. TV sales in recent years—a product of previous banner years as consumers bought flat-panel HDTVs in droves—the industry still sells nearly 40 million units annually. Consumers are getting bigger and better screens for less money. CEA forecasts sales of 4K Ultra HDTVs to ramp quickly from 800,000 units this year to 3 million units next year—not bad considering that 2014 is the first full calendar year with a range of 4K Ultra HD models from multiple brands.

What makes a 4K Ultra HDTV, and what is in the realm of possibility for the next generation of displays? CEA worked with the industry to document the minimum performance attributes that 4K Ultra HD displays provide today:

- **Display Resolution**—a 4K Ultra HD display has at least 8 million active pixels, with at least 3,840 horizontally and at least 2,160 vertically.
- **Aspect Ratio**—the width-to-height ratio of the display’s native resolution is 16:9 or wider.
- **Upconversion**—the display is capable of up scaling HD video and displaying it at ultra-HD display resolution.
- **Digital Input**—the display has one or more HDMI inputs supporting at least 3,840 × 2,160 native content resolution at 24p, 30p, and 60p frames per second. At least one of the 3,840 × 2,160 HDMI inputs shall support HDCP v2.2 or equivalent content protection.
- **Colorimetry**—processes 2,160p video inputs encoded according to ITU-R BT.709 color space, and may support wider colorimetry standards.
- **Bit Depth**—has a minimum bit depth of 8 b.

There are five important ways to improve picture quality: resolution, frame rate, colorimetry, bit depth, and dynamic range. Resolution is easy: double HDTV’s 1,920 pixels in the horizontal direction, and double the 1,080 pixels vertically to get four times the spatial resolution and arrive at 4K Ultra HD’s 3,840 × 2,160 minimum resolution. Done. Ultra-HDTVs do this brilliantly today.

But video is moving pictures, which brings us to frame rate or what we might call temporal resolution. It is convenient to think about video as still pictures captured at 24, 30, or 60 frames per second, but nothing is really still. The shutter opens for a moment, during which time parts of the scene move around, especially with sports. Resolution will not save the day; it can make it worse in some cases. The still parts are super sharp, which accentuates the blurred motion. The British Broadcasting Corporation has been at the forefront of testing the interaction between ultra-HD resolution and frame rate. Preliminary results of perceived quality under different frame rates suggest that most ill effects from judder and blurring are cleaned up in the range of 100–120 frames per second. Today, HDMI can handle ultra-HD resolution up to 60 frames per second, which makes for stunning movies and TV shows. Very soon, the consumer will be able to dial the knob between more pixels and faster pixels.

Here is the oversimplified version of what colorimetry is and how displays are doing a better job showing what our eyes see in the real world. Color TV has always used a blend of red, green, and blue primaries to generate the palette of colors you see. International standards such as BT.709 define exactly what the red, green, and blue colors are and how to represent their brightness numerically, among other things. The goal is this: the TV needs to produce the same mix of red, green, and blue that the studio intended when the program was created.

It might seem a little anachronistic to reference BT.709, originally developed for HDTV in 1990, in the latest ultra-HDTV definition when there is an equivalent standard BT.2020 for ultra-HD. The TV industry is using the resolution and frame rates from BT.2020, while relying on the existing colorimetry of BT.709. 4K Ultra HDTVs are not precluded from using BT.2020 or other wider color spaces, but to guarantee interoperability with existing content and workflows, BT.709 must be supported.
The last area of display improvement comes from extending the dynamic range by increasing the maximum white level while decreasing the minimum black as well as making all available colors brighter and adding more of the colors the human eye can see. Research has shown consumers would prefer images that are up to 200 times brighter with 4,000 times more contrast than today’s broadcast and Blu-ray standards, so there is plenty of opportunity for improvement.

There is some debate as to what the high end of the brightness range should be. Movies are graded to a brightness of 100 nits. TVs today can produce a few hundred nits. Should the high end be 1,000 nits or even up to 4,000, as has been suggested by some? What should the optical to electrical transfer function be at the camera end to make the best use of the dynamic range? Dolby, Technicolor, and others are hard at work developing systems that answer these questions and capture, deliver, and display high-dynamic-range TV.

TOM HANKS VERSUS DIGITAL IRA

Many people consider Tom Hanks’ character in The Polar Express (2004) to be solidly in the “uncanny valley,” that creepy no-man’s-land where cartoons or robots look close to human but not quite right. Prof. Masahiro Mori coined the term uncanny valley in 1970, referring to the sudden dip in comfort level as people interact with robots, which increasingly appear more like natural humans. The comfort level rises to a point where the robot approaches a human likeness, then falls into the uncanny valley of a negative emotional response (Figure 1).

Motion amplifies the response, as shown in Mori’s depiction of affinity versus human likeness. It makes intuitive sense that we have a heightened response to something animate when it triggers a negative reaction. Of course, motion is what is needed in the movie business. Our acute visual perception and the steep wall of the uncanny valley combine to make creating digital actors extremely challenging.

Now compare Digital Ira to Hanks in The Polar Express. Digital Ira is an active project at the University of Southern California (USC) Institute for Creative Technologies (ICT) in collaboration with Activision that aims to create a photorealistic digital actor. The important distinction between Digital Ira and USC ICT’s previous Digital Emily project is the goal of generating a digital actor in real time that could be used in tight closeups. Imagine video games in which characters are indistinguishable from filmed actors and you can understand why Activision is partnering on the project.

Digital Ira started with a real actor scanned with high-resolution cameras on a special light stage as the actor went through 30 facial expressions. The team selected eight expressions that would be the real-time rendering output. A big part of the hard computation is done offline to generate a topographical mesh that captures how expressions flow from neutral to a smile, for example. The game engine, the real-time part, has to deal with all the optical nuances that make for convincing video, like ambient shading and eye refraction. Search for “Digital Ira” and watch the short demonstration video at the ict.usc.edu Web page then decide for yourself how close we are to having real-time digital actors.

The importance of digital actors goes beyond stunning games and better action movies. Instead of replacing actors in a few CGI scenes, storytelling can fundamentally change with digital actors. Stories do not need to have a fixed plotline from start to finish. The boundary between games and movies will vanish.

PRESENCE ACCOUNTED FOR

What is different this time around, besides the US$2 billion purchase of Oculus, that suggests VR can be a hit with consumers? Many experts believe that hardware and software are advanced enough to finally achieve what experts call presence on platforms that are cost effective for consumers. Well-executed VR should convince your brain you are present in the experience and not viewing that world from the outside. It is the difference between looking through a portal and being teleported. Suspension of disbelief is not needed when motion and vision are integrated. Turn your head in a movie theater, and you break the connection. Turn your head wearing a VR headset, and the immersive experience is reinforced.

Four big-name players are in the news with announced or expected plans for VR products. After showing prototypes at the 2014 International Consumer Electronics Show (CES), in March, Sony Computer Entertainment announced Project Morpheus, a VR system that leverages the PS4’s phenomenal graphics computing power. Morpheus uses a visor-style display with inertial sensors and PlayStation Camera to track head movement (Figure 2). Morpheus aims to completely change the gaming experience. Sony says, “…the player can use a PlayStation Move (PS Move) Motion Controller as an object, such as a sword. Morpheus will reproduce the player’s hands and sword within the game so the player feels like they are physically fighting off enemies with their sword in the virtual world.” Morpheus integrates three-dimensional (3-D) audio too, so that as the player’s head moves, sounds move in an immersive 360º environment.

At the other extreme is Google Cardboard—literally a folded-up cardboard holder for your Android phone. Drop your
phone in, hold it up to your eyes like a Fisher-Price Viewmaster, and voilà—VR. The phone’s hardware handles motion tracking. The Google Cardboard app provides integration so you can fly around in Google Earth or watch YouTube videos. There are third-party apps available in the Google Play store. Few would argue that Cardboard provides real presence to the user, but it goes a long way to demonstrate how much computing power we carry around.

From a Kickstarter campaign to a US$2 billion purchase by Facebook, Oculus has become synonymous with the future of consumer VR. It has done so by tackling head-on everything that leads to sim sickness or what Oculus CEO Brendan Iribe calls “the uncomfortable valley” that results when a VR display does not match what the brain expects.

What does it take to tame sim sickness? Michael Abrash, who headed Valve’s VR work before becoming chief scientist at Oculus, suggested this level of performance at Steam Dev Days in January 2014: 20-ms latency from head motion to picture, 95-Hz refresh, 3-ms pixel persistence, 110° field of view, and tracking accuracy down to the millimeter. It is not surprising that the Oculus Development Kit 2 (DK2) specs hew closely to Abrash’s earlier statement on what it takes to achieve sickness-free presence. Oculus is still filling orders for the DK2 and has announced its third-generation prototype named Crescent Bay.

The last big company making a VR splash is Samsung, which has announced a product that combines Oculus software with a Google Cardboard approach. Samsung’s Gear VR is a headset that holds a Samsung Note 4 (and only the Note 4) and provides lenses for 3-D effects along with a trackpad and focus controls.

Gaming dominates VR news, but the immersive experience does not have to be computer-generated graphics. At the 2014 International CES, Kolor, a French company specializing in image stitching and virtual tour software, combined a 360° camera footage shot from a hot-air balloon with the Oculus Rift. Put on the headset and you are transported to the air above France. Look up and see the balloon. Look to the left, and there is another balloon nearby. Look over the edge of the basket and down to experience that jolt of vertigo that only comes with real presence.

**WHEN IT HITS YOU**

“One good thing about music, when it hits you, you feel no pain.”

—Bob Marley

Some would argue that listening to compressed songs ten years ago was quite painful. Listening to music has gone through the most obvious and profound quality/convenience tradeoff and is poised to regain all of the quality lost in our rush to pack songs onto portable devices. Back in 1998, the MPMan launched in Asia, and the Diamond Rio sold in the United States, each with just 32 MB of memory, were able to hold about six compressed songs. As a result, we crushed music files as small as possible to fit on the limited space of available flash memory or, once the iPod hit in 2001, the 5 GB on Toshiba’s 1-in hard drive. While storage and broadband speeds marched ahead at the pace of Moore’s law, music and consumer electronics companies together built out a robust digital distribution system for music, which sets the stage for finally putting the quality back in music with high-resolution audio.

High-resolution audio is defined as lossless audio that is capable of reproducing the full range of sound from recordings that have been mastered from better-than-CD-quality sources. High-resolution audio equipment and music files are expected to support 96-kHz/24-b sampling or higher quality, beating even CD audio specified at 44.1 kHz/16 b. Why such a high bar? Why the focus on getting master-quality files all the way to consumers? This is in part because storage and devices can now readily handle the files, but more importantly because consumers want quality. Nine out of ten consumers say sound quality is the most important component of a quality audio experience (from CEA’s *Notions of Quality: Audio Expectations of Consumers*).

A host of companies, including Sony, Onkyo, and Pioneer, are already backing high-resolution audio. In fact, more than 50 companies displayed high-resolution audio products at the 2014 International CES. About a dozen digital music stores, like HDTracks and Blue Coast Records, sell compatible recordings.

Prepare to be amazed at the new technologies and astounding improvements to all forms of entertainment made possible by the consumer electronics you develop.

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