Standards Bring Sharper Vision to Medical Imaging

— by John Phillips, Pleora Technologies

The noisy factory floor may seem worlds away from the sterile beeps and hums of a hospital, but the robotic arms and networked inspection cameras along a manufacturing line have played an important role in the continuing evolution of medical imaging systems.

In today's state-of-the-art operating room, staff use a real-time network of cameras, sensors, and displays to precisely navigate robotic surgical tools that minimize damage to healthy tissue, improve results, and speed recovery. Following surgery, a vision-enabled pharmacy robot accurately compounds drug mixtures and safely administers pain medication.

Supporting the development of these sophisticated medical imaging systems is a set of global vision standards developed for and widely adopted across the industrial machine vision market. Increasingly, medical imaging system manufacturers and hospital administrators are relying on these vision standards to guide design and purchasing decisions.

This column introduces the GigE Vision®, USB3 Vision™, and GenICam™ standards and discusses how the standardization of high-performance video transmission has benefited medical imaging systems. Future columns will take a closer look at the specific design and performance benefits offered by standards-compliant video interfaces in the networked operating room, telepresence robots, and other healthcare imaging applications.

Vision Standards Simplify Design

To meet the needs of demanding imaging applications, high-performance video systems must transfer live-action, high-resolution video from cameras or image sensors to computers or displays in real-time, with high reliability and low, consistent latency (or delay). The video interface — the hardware and software used to format the imaging data, send it over a cable or wirelessly, and receive it at a computer or display — is a small part of the overall system, but has a disproportionately large impact on the performance, usability, cost, and scalability of the final product

As machine vision moved from research labs onto manufacturing floors throughout the 1980s and early 1990s, video interfaces were often based on proprietary designs. These custom solutions met performance criteria, but were expensive and time-consuming to develop and maintain while introducing an "integration nightmare" in multi-vendor environments.

Existing standards were also adapted for machine vision products. The TIA/EIA-644 low-voltage differential signaling (LVDS) standard, commonly used in telecom and consumer communications to transfer video to computer monitors and displays, was employed in industrial cameras and machine vision applications. Camera Link®, introduced in 2000, was the first purpose-built standard designed for machine vision products.

Camera Link interfaces, along with LVDS and connections based on the HDMI/DVI television standard, are now often found in medical imaging applications. As imaging systems perform more complex tasks, and end-users seek easy-to-use solutions that help meet operating cost objectives, the limitations posed by these interfaces are more apparent.

Each of these interfaces requires a dedicated connection between the cameras and endpoint, whether that's a computer for image analysis or a display panel for observation. In applications where images are displayed across multiple screens — such as image-guided surgery — the cabling required for these umbilical connections becomes costly, complex, and difficult to manage and scale.

Moreover, these interfaces require a PCIe frame grabber at each endpoint to capture data. This limits the types of computers that can be used, drives up component costs, and increases complexity. End-users are also "locked in" to the frame grabber vendor for support, relying on them to write drivers for specific operating systems and processing architectures. In addition, expensive switching is required to support real-time video networking.

Recognizing these limitations, the vision industry created a set of standards aimed at simplifying design, lowering system costs, and making it easier for end-users to install, upgrade, and maintain imaging systems by regulating the transport mechanism, video format, and control mechanisms.

The GigE Vision and USB3 Vision standards reduce design and deployment costs by enabling the transmission of full resolution uncompressed video with low, consistent latency over Ethernet or USB 3.0 cables. GigE Vision additionally enables transmission of compressed images (JPEG, JPEG 2000 and H.264). Per-frame metadata, such as data and time of acquisition and imaging equipment used, is transmitted with the images over the GigE or USB3 link for easy integration with DICOM-compliant software and hardware. GenICam allows manufacturers to use same applications design framework for any compliant camera or imaging device, regardless of its vendor, to simplify the integration of products into larger systems.

GigE Vision

GigE Vision, launched in 2006, standardized video transfer and device control over Gigabit Ethernet (GigE) and was later expanded to encompass 10 GigE and wireless Ethernet. Today, GigE Vision is the most widely deployed video interface standard for industrial applications, and is now gaining a strong foothold in defense imaging and medical applications.

With GigE Vision interfaces, imaging data is transmitted directly to the Ethernet port on a computing platform. There is no need for a PCIe frame grabber, which means any type of computer can be used, including laptops and tablets. In applications where images are transmitted through umbilical connections, Ethernet cables cost less and are simpler to install and maintain than bulky Camera Link cabling and connectors. With the long reach of GigE cables — up to 100 meters over standard Cat 5/6 copper cabling versus 10 meters for Camera Link — processing and image analysis equipment can be located outside of sterile environments.

With 10 GigE interfaces — which support ten times the bandwidth of GigE — multiple image sources can be transmitted simultaneously over a switched Ethernet network to a processor for 3D image generation. GigE Vision delivered over an 802.11 wireless link allows portable x-ray panels to be positioned comfortably without fear of cable entanglement.

When the GigE Vision standard was first introduced, it was valued primarily for its low cost and 100 meter reach in umbilical camera-to-computer connections. Today, designers are taking advantage of Ethernet's inherent networking flexibility to build real-time switched video networks connecting cameras and endpoints, including analysis computers, display dashboards, and storage devices. GigE Vision brings a whole new dimension to applications, allowing one camera to send video to multiple endpoints, multiple cameras to send video to one endpoint, or combinations of the two.

USB3 Vision

Building on the concepts developed for GigE Vision, the machine vision industry standardized the transport of high-speed imaging and video data over a USB 3.0 cable with the release of USB3 Vision in February 2013.

With USB3 Vision, video and data is transmitted from cameras and sensors

GigE Vision	USB3 Vision
Uses common Ethernet infrastructure (ports widely available on most computing platforms, cabling, network interface cards, switches)	Uses USB 3.0 ports common on most computing platforms and off-the-shelf cables
Data transfer rates up to 125 MB/s with GigE, and 1.25 GB/s with 10 GigE	Data transfer rates up to 375 MB/s
Cable lengths up to 100 meters; longer with widely available switches	Supports cable lengths up to 5 meters
Networking flexibility allows one camera to send video to multiple endpoints, multiple cameras to send video to one endpoint, or combinations of the two.	Supports "hot-plugging" and "hot-swapping" of components with automatic detection and software configuration, aggregate multiple cameras to a single USB 3.0 port using an off-the-shelf USB 3.0 hub
Ability to power cameras over the Ethernet cable (IEEE 802.3af Power over Ethernet)	Ability to power the camera over the USB cable

Table 1: GigE Vision and USB3 Vision standards simplify integration, maintenance, and interoperability of medical imaging systems.

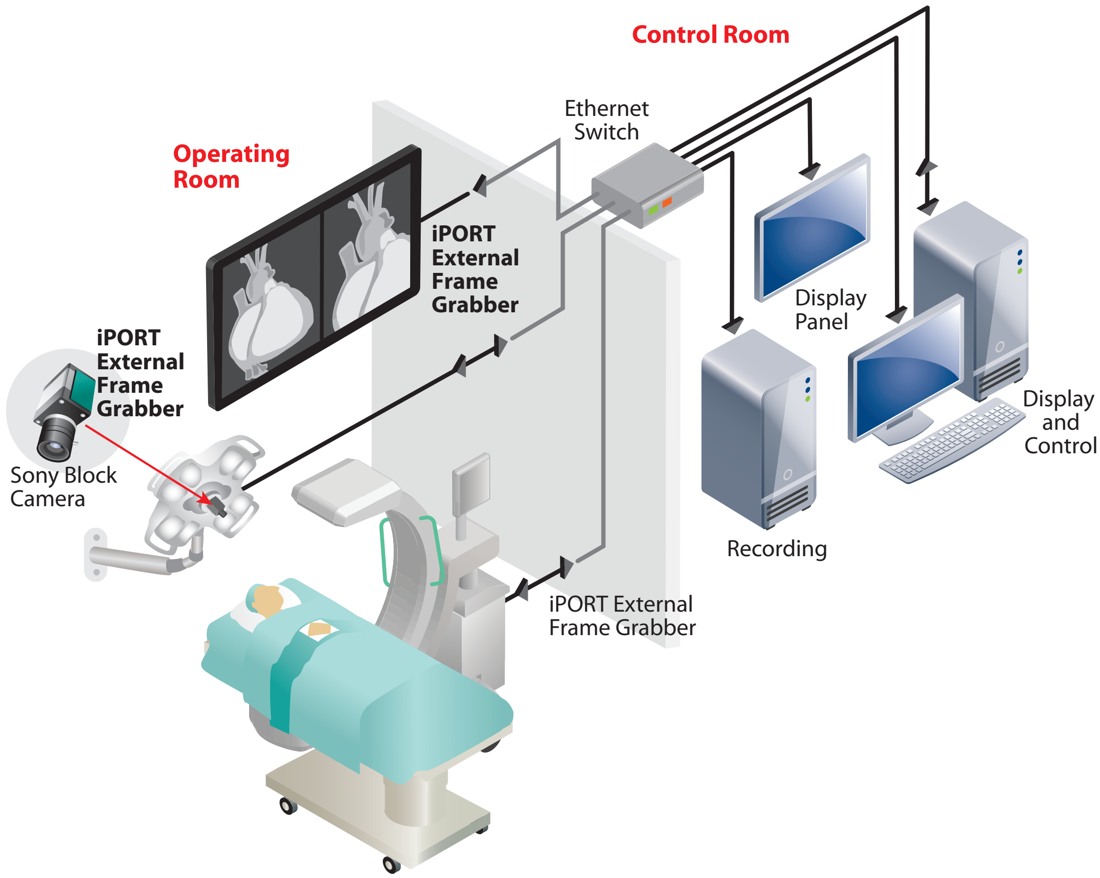

Diagram 1: Images from an X-ray detector and lamp-head camera are converted to GigE Vision and multicast to display panels in the operating room and computing platforms used for image processing, storage, and monitoring.

directly to existing ports on a computer, laptops, or tablet over flexible USB 3.0 cabling. The USB 3.0 bus delivers throughput approaching 3.0 Gb/s over short distances, and is ideal for applications such as transmitting images from a microscope camera directly to a port on a laptop or tablet.

Traditionally, applications like these have used bulky Camera Link cabling and a PCIe frame grabber to capture images at the computer, resulting in more complex systems, higher costs, and limited component selection. Moreover, USB 3.0 cabling is widely available and supports simple plug-and-play installation.

GenICam

The third standard, GenICam, was launched in 2006 shortly after the release of GigE Vision. GenICam defines a generic programming interface for the computer control of cameras and other imaging products that transmit video. It supports all cameras types, no matter what video interface technology they use or features they offer.

GenICam cost-reduces the design, deployment, and maintenance of high-performance video applications by allowing the same design framework to be used for different types of cameras and imaging products. It also simplifies the integration of new cameras into larger systems by employing an XML-based computer-readable datasheet and defining a Standard Features Naming Convention (SFNC). By standardizing software terms, such as “gain” instead of “brightness”, end-users can use the same interface to program applications for any compliant camera or imaging transmission product, regardless of its vendor.

Further Reading: Vision standards are obviously far more complex than outlined in this column but information on the standards is readily available online. Pleora has played an active role in the development and evolution of GigE Vision, USB3 Vision, and GenICam. Our web site, http://www.pleora.com, provides a good starting point for designers wanting to learn more.

Benefits for Designers and End-Users

Too often, well-intended standards fail to deliver the right combination of design, cost, and performance benefits. For the machine vision market, camera manufacturers, component suppliers, and end-users joined forces to create a set of open, global standards to make it easier to install, upgrade, and maintain imaging systems and cameras.

As healthcare imaging applications multiply, system designers face a set of unique challenges. In my next column, we’ll take a closer look at how GigE Vision and USB3 Vision-compliant products provide designers with a “checkmark” to address increasing performance, scalability, and interoperability concerns. ✷

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