A Sharper Vision for the Networked Operating Room

— by John Phillips, Pleora Technologies

The discovery of x-rays in 1895 marked the beginning of a new era in medical services, with physicians greatly improving the standard of care by using scans to identify issues, make diagnoses, and provide treatments. Now, thanks to a new wave of technological advancements, imaging systems are once again helping healthcare providers take medical services to a new level. Nowhere is this more apparent than in today's state-of-the-art operating rooms, where staff use real-time networks of cameras, sensors, and displays to make image-guided surgical decisions that minimize damage to healthy tissue, improve results, and speed recovery.

Meanwhile, outside of the operating room, networked imaging systems are being used to confer with remote specialists, increase hospital efficiencies, and reduce costs. For example, vision-enabled telepresence robots are being used to provide hospital and home-based patient care, and real-time video feeds at nursing stations are helping streamline operating room scheduling.

As applications multiply, imaging system designers face a set of challenges unique to the medical world. First, even as the systems handle increasingly sophisticated analyses, they must be intuitive and easy to use for staff in operating rooms, nursing stations, and administrative offices. Second, budget pressures mean the systems must deliver enhanced performance without sacrificing existing investments in specializing imaging devices and processing equipment. And finally, the systems must be simple to maintain and scale.

In considering these challenges, a key early decision for system designers is choosing the video interface – the technology used to transfer data from a camera or image sensor to a computer or display. Although the video interface is only a small part of the overall medical imaging system, it has a large impact on the usability, cost, and scalability of the final product.

Minimizing Complexity and Cost

Traditionally, medical imaging systems have used point-to-point connections between a camera or image sensor and a computer. These connections have typically been based on proprietary video interfaces or older interfaces like LVDS, HDMI/DVI, or Camera Link®, and come with a host of limitations. Proprietary interfaces are expensive and time-consuming to develop, while LVDS and Camera Link drive up cost and system complexity by requiring each camera and display panel to communicate over a dedicated connection. 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, the interfaces do not support real-time video networking without employing expensive switching, and they require a PCI frame grabber at each endpoint to capture data, limiting the types of computers that can be used and driving up cost.

To address these issues, many medical imaging system designers are turning to networked video systems based on Gigabit Ethernet (GigE) video interfaces. GigE is a natural choice for video transmission in medical imaging systems. It allows designers to fully support required point-to-point connections, while gaining the flexibility of video networking, the ability to interwork with a range of computing platforms, and the benefits of light-weight, low-cost cabling. Moreover, video delivery and video applications development has been standardized for the GigE platform by users in the machine automation world. The GigE Vision® and GenICam™ standards provide systems designers with a "checkmark" to address scalability and interoperability concerns for hospital administrators.

With GigE interfaces, imaging data is received using the Ethernet ports that already exist in most computers. By eliminating the need for PCI frame grabbers to connect cameras to the computer, designers can lower system costs. They can also minimize footprint and reduce system complexity by migrating to smaller form factor, lower-power computing platforms, such as embedded PCs, single-board computers, laptops, and tablets.

The more flexible, field-terminated Ethernet cables cost less and are simpler to install and maintain while supporting longer reach than the bulky cabling and connectors of legacy interfaces. Video, control data, and power are transmitted over one cable. This lowers component costs, simplifies installation and maintenance, and reduces "cable clutter."

Preserving Existing Equipment

One of the benefits of GigE Vision is the wide range of commercially available video and networking products that comply with the standard. This makes it relatively straightforward for medical system designers to create a real-time networked operating room without sacrificing existing investments in imaging equipment based on proprietary, Camera Link, or LVDS interfaces. The GenICam™ standard, incorporated into a range of high-speed video standards including GigE Vision, provides a universal programming interface that ensures interoperability between imaging products and simplifies the design of software applications that can be used across multiple medical imaging systems.

In the example shown in Diagram 1, images from an x-ray detector are sent over an existing Camera Link or LVDS interface to an external frame grabber, where the images are converted to a GigE Vision-compliant video stream. A second external frame grabber converts images from a Sony block camera mounted in the lamp head into the same compliant GigE format. These image feeds are aggregated at a basic switch and multicast to processing, analysis, display, and recording equipment.

The long reach of Ethernet — 100 meters point-to-point over ordinary Cat 5/6 cabling — means processing and analysis equipment can be located outside the sterile environment. This reduces the costs of sterilizing equipment, lowers the risks of patient infection, and allows data to be shared more easily shared across multiple departments.

At the computer, the video streams in through the Ethernet port, allowing the use of lower cost, lower power, smaller form-factor computing platforms, including laptops and tablets. The video processor highlights

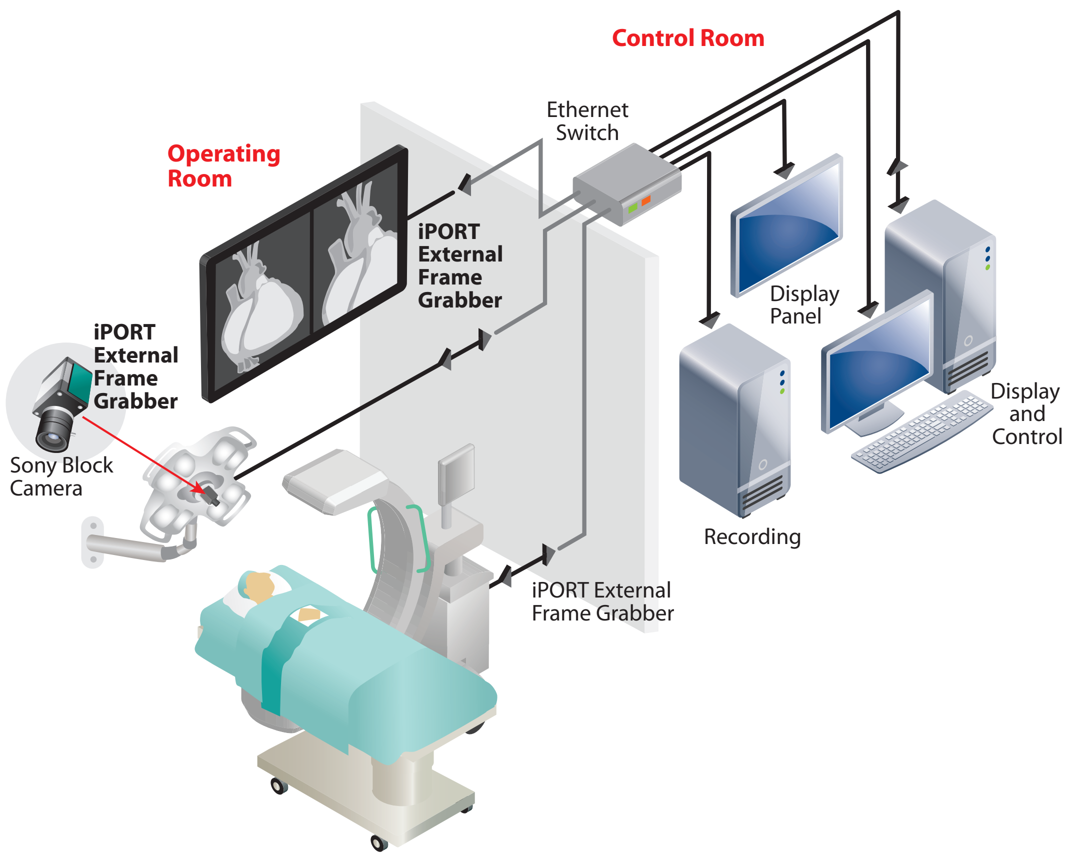

Diagram 1: Images from an x-ray detector and lamp head camera are converted to GigE Vision, processed, and multicast to various display panels in the operating room and hospital.

areas of interest, including pre-op images, and overlays vital signs information. The composite image is then multicast over the Ethernet network to various displays, with end-users able to easily change an imaging source or destination without configuring hardware or software. In the operating room, an external frame grabber converts the GigE Vision image stream to HDMI/DVI signals for viewing on a high-definition monitor used by the surgeon to track real-time patient data from different imaging devices and systems.

Expanding the Operating Theatre

Integrating previously isolated image sources and patient data onto a common network and aggregating the information on a single dashboard can increase the situational awareness of operating room staff, with faster decision-making and improved communications across the operating team contributing to improved patient safety and quality of care. The ability to multicast real-time video from different image sources to various endpoints without reconfiguring hardware or software may also speed procedures and enable other opportunities to improve care. For example, real-time video from the operating theatre can be more easily shared with other departments, nursing staff, or remote specialists who can provide live expert advice during the operation.

With proper implementation, Ethernet-based networks can easily support “glass-to-glass” latency requirements for real-time medical imaging systems. Research shows the ability to perform surgical tasks begins to decrease when glass-to-glass video latency exceeds the range of 300 to 500 milliseconds (ms). With GigE-based networks, medical imaging system designers can easily achieve end-to-end latency of 200 ms or less. In addition, by basing the network on Ethernet new imaging sources, display panels, and cameras can be easily added to the system, often with plug-and-play simplicity.

Interfaces based on the GigE Vision also speed the design and boost the performance of advanced applications such as full-motion video, portable x-ray panels, and the robots used for a widening range of modalities in clinical, hospital, and home-based care.

In full-motion video applications, for example, fluoroscopy that uses multiple moving x-ray sources to obtain real-time images of a patient, legacy umbilical interfaces are uneconomical and cumbersome. 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. For patients with limited mobility, GigE Vision delivered over an 802.11 wireless link allows portable x-ray panels to be positioned comfortably without fear of cable entanglement.

The Operating Room of the Future

Imaging technology is increasingly becoming the electronic eyes of a surgeon, with real-time video networking enabling new levels of precision, insight, and diagnoses to improve patient outcomes. Many of the performance benefits offered by fully networked imaging systems in and outside of the operating room can be traced back to a very early design choice. Designing or upgrading medical imaging systems with off-the-shelf GigE Vision interfaces allows manufacturers to shorten time-to-market, reduce risk, and lower system cost and complexity, while delivering interoperability and performance benefits to enhance the value of their solutions. ✹

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