Million-seller on the Advance into Machine Vision

USB 3.0: Promising in Market Penetration and Convincing in Technical Merits

The Universal Serial Bus (USB) is the most common serial peripheral interface in the history of computing. Present in virtually 100% of all computers, it is the standard for most computing peripherals and sells billions of units every year. To understand how USB 3.0 will impact vision in the future, it's important to first understand the road that led to its development.

The USB 1.0 specification was released by the USB Implementers Forum (USB-IF) in 1996 and ran at 1.5 Mbit/s (low-speed) and 12 Mbit/s (full speed). While useful for lower data rate peripherals, it was not until USB 2.0 (high-speed USB) was introduced in 2001 with a maximum raw data throughput of 480 Mbit/s (60 MByte/s) that the standard became useful for applications such as video and data storage, and led to the creation of the first USB 2.0 digital video cameras.

Improving Performance with USB 3.0

The USB 3.0 specification was released in 2008 with the goal of building on the strengths of USB 2.0 while addressing many of its limitations. The USB 3.0 specification increases raw data throughput to 5 Gbit/s (640 MByte/s). Though 8b10b encoding sets a practical limit of about 500 MByte/s, this still represents a substantial performance improvement over USB 2.0. USB 3.0 adds five wires for a total of nine wires in the connectors and cabling, and utilizes a unicast dual-simplex data interface. This allows data to flow in two directions at the same time; an improvement over USB 2.0's half-duplex unidirectional communication model. The USB 3.0 specification preserves the legacy bulk and isochronous data transfer mechanisms of USB 2.0. Bulk transfers are guaranteed delivery, but not bandwidth, while isochronous transfers provide deterministic communication with guaranteed bandwidth, making this mechanism well-suited to the transmission of real-time data. USB 3.0 significantly increases isochronous throughput from approximately 24 MByte/s to a total of 384 MByte/s.

Reduced System Overhead

The USB 3.0 architecture has many similarities to PCI Express (PCIe), and although there are obvious functional differences between them, they both aim to increase bandwidth and lower power consumption. USB 3.0 maintains much of the existing USB 2.0 device model, and like USB 2.0, is still a host-directed (aka master-slave) protocol. Every transaction either goes to or comes from the master, which is typically the host computer. One important change, however, is the signal-

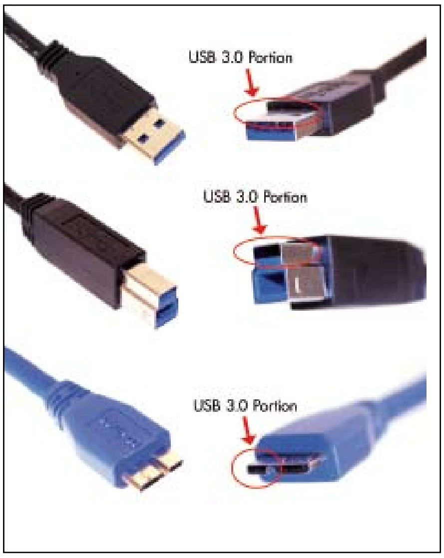

Fig. 1: Connector and cable-backward compatibility was a core design goal with USB 3.0

ing method. The USB 3.0 specification uses asynchronous signaling, which allows a device to notify the host when it is ready for data transfer. This significantly reduces system overhead and CPU usage compared to the polling mechanism in USB 2.0. A variety of other protocol improvements, such as streaming support for bulk transfers and a more efficient token/data/handshake sequence, are designed to improve system efficiency and reduce power consumption.

Fig. 3: Repeaters like Newnex's FireNEX-uLINK can extend USB 3.0 cable distance

Backward-compatibility Provided

In addition to an improved architecture and higher bandwidth, USB 3.0 also provides more efficient power management and increased power delivery over USB 2.0. The amount of current draw for USB 3.0 devices operating in SuperSpeed mode is now 900 mA, resulting in an increase in total power delivery from 2.5 W to 4.5 W (at 5 V). USB 3.0 also offers an improved mechanism for entering and exiting low-power states, depending on whether a device is active or not, and eliminates continuous power consuming polling. Although the USB 3.0 cable contains five new wires, it is still backward-compatible with USB 2.0, allowing consumers to continue to utilize their existing peripherals with a USB 3.0-enabled computer, or USB 3.0 devices with a legacy computer (see fig. 1). USB 3.0 Standard-A receptacles are backward-compatible with USB 2.0 but add new pins for USB 3.0 signals. The new Standard-B and Micro-AB receptacles are also backward-compatible (see fig. 1).

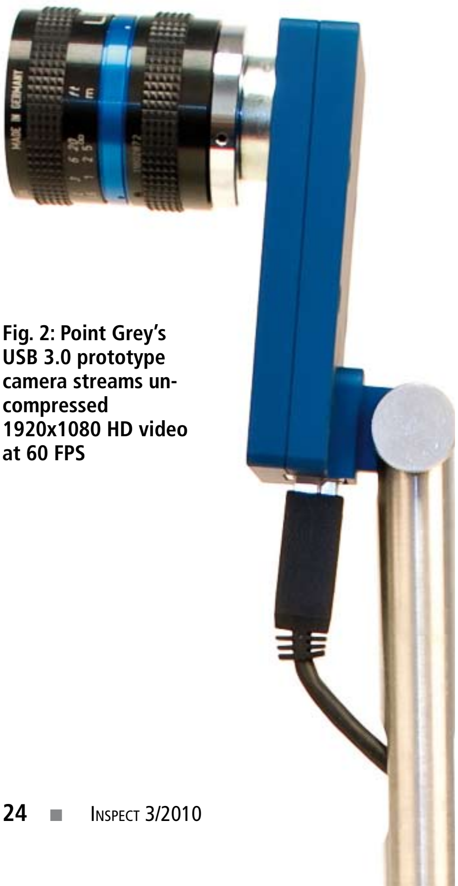

Fig. 2: Point Grey's USB 3.0 prototype camera streams uncompressed 1920x1080 HD video at 60 FPS

First USB 3.0 Cameras Presented

An abundance of USB 3.0 devices are already available, ranging from motherboards and hard drives, to interface cards and hubs. At the Consumer Electronics Showcase (CES) in January 2010, the USB-IF announced the first 17 consumer products that passed USB 3.0 compliance and certification testing. The silicon required to provide low-level connectivity for USB 3.0 devices is now available from companies like NEC, Fresco Logic, and Texas Instruments. This allowed Point Grey Research, Inc. to demonstrate the world's first USB 3.0 digital video camera at the 2009 Intel Developer Forum (IDF) in San Francisco (see fig. 2). The high-definition demo camera was shown streaming 120 MByte/s of raw, uncompressed 1080p60 video, generated by a high-performance Sony CMOS image sensor, to a Fresco Logic host controller. Other USB 3.0 products made their debut at CES 2010, including the FireNEXuLINK from Newnex Technology (see fig. 3), the world's first USB 3.0 active repeater capable of extending USB 3.0 signals up to 12 m in length.

Small Size and Low Cost

When compared to the existing lineup of digital interfaces, USB 3.0 has its strengths and limitations. The increased 500 MByte/s throughput and improved 4.5 W of power delivery is well-suited for many of the high-speed, multi-megapixel image sensors on the market today (see fig. 4). While Camera Link is still the bandwidth leader at approximately 680 MByte/s with a full eight-tap configuration, many customers may choose to sacrifice some pixels or frames per second in exchange for the easier to use and more cost-effective USB 3.0 alternative. Like FireWire, the USB 3.0 specification provides power and data over a single cable; has guaranteed, truly isochronous bandwidth; and is well-matched to applications requiring small size and low cost. However, while USB 3.0 is almost 10 times as fast as FireWire and GigE, FireWire provides more power (up to 45 W) and GigE's maximum cable length is superior.

Standard Protocols in Discussion

There are other practical factors to consider when evaluating USB 3.0 for vision applications. An important one is the control protocol implemented on the camera. FireWire and GigE cameras use the 1394-based Instrumentation and Industrial Digital Camera (IIDC) and GigE Vision standards, respectively, which enable compliant cameras to be used with any vision software package that also supports these standards. USB 2.0, on the other hand, has no such common protocol. The USB Video Class (UVC) is not appropriate for industrial digital cameras, leading some manufacturers to create their own proprietary camera control interface and others to use IIDC. The Automated Imaging Association (AIA), which historically has had no involvement in USB 2.0, announced at its January business conference a new USB 3.0 standard committee to evaluate appropriate protocols like IIDC and GenICam.

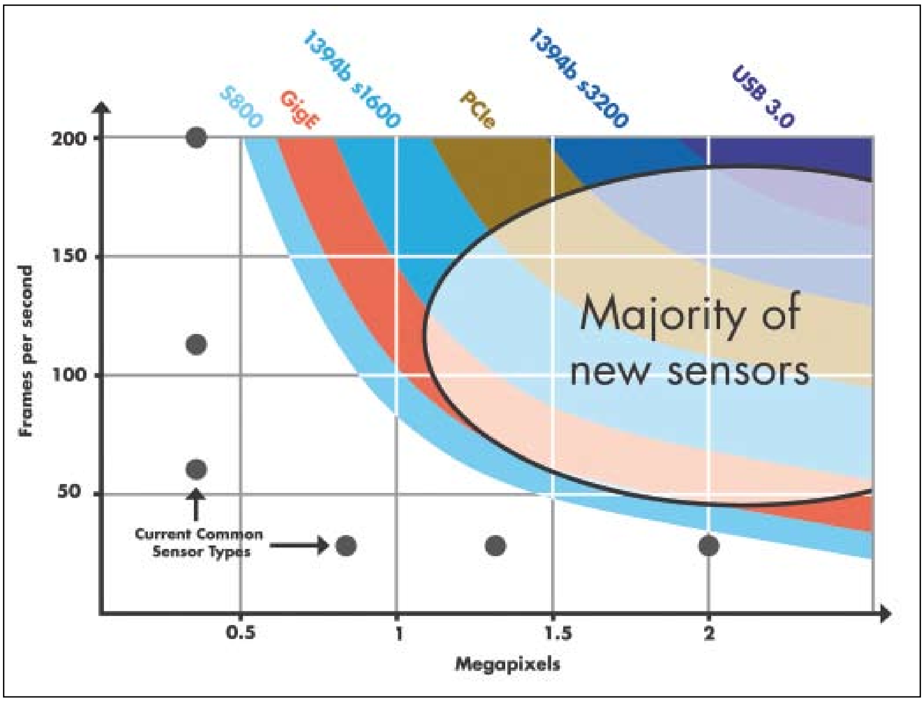

Fig. 4: Most existing digital interfaces do not provide the required bandwidth for many new image sensors

Long-distance Cabling in Development

Another consideration is cable length. The maximum length is not explicitly specified in the USB 3.0 standard. However, the standard does describe the relationship between wire gauge and maximum length in order to achieve USB 3.0 voltage drop requirements. For example, a cable can be up to 5.3 m long when using an American Stranded Wire Gauge (AWG) of 20. In the majority of cases, the host computer system is located within this distance. A variety of high-performance and cost-effective solutions will rapidly become available to address situations where longer distance is required. USB 3.0 hubs and repeaters already are in production, and work on signal-corrected long-distance cables, equalizer technology like EqcoLogic's EQCO5000, and long-haul optical solutions is in progress. Other USB 3.0 cable and connector products geared toward industrial and machine vision are under development, including screw-locking connectors, high-flex chain cables, and so on.

Technical Merits Boost USB 3.0

It is clear that consumer market acceptance of USB 3.0 will be ahead of the vision industry. However, USB 3.0 promises to open up new applications in machine and computer vision, as well as in non-industrial markets where USB 2.0 already has widespread acceptance. While there is no single digital interface that works best for all vision applications, on technical merits alone USB 3.0 will be a strong contender, and will certainly become an important camera interface in the years to come.

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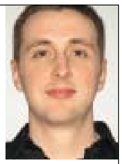

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