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An Icron Technologies White Paper »

Meeting New Technological Demands in Machine Vision with SuperSpeed USB 3.0

» A review on how USB has evolved for popular adoption in machine vision applications

EXTREME USB®

Abstract

USB (Universal Serial Bus) is undisputedly the most successful computer connection interface to date, with well over ten billion USB devices already in the market and increasing every day. Up to now, the same degree of adoption has not transitioned to machine vision applications due to the relatively low throughput rate and cable distance limits of USB 2.0 when compared to the other industrial camera interfaces such as FireWire, GigE Vision and Camera Link.

Today, with a 10x improved data throughput rate over USB 2.0 from 480 Mbps to 5 Gbps, USB 3.0 is well poised to become a dominant machine vision camera interface; capable of supporting higher parameters of resolution (4K Ultra High Definition), frame rates and color depth. Unfortunately, the improved bandwidth came at the expense of cable distance, reduced to approximately 3 meters. In order for USB 3.0 to thrive as a camera interface in machine vision applications, the cable length limitation must be overcome.

This white paper examines the benefits, performance and evolution of USB as a viable machine vision camera interface.

The Popularity of USB

Due to its flexibility, simplicity and relative affordability, USB has become the de facto standard for computer peripheral connectivity spanning broad markets and applications. It was only a matter of time before USB would evolve to support today's machine vision camera requirements.

Despite the advantages USB 2.0 offers to typical computer-centric peripherals such as keyboards, mice, flash drives, external hard drives, audio devices and low-performance cameras for consumer applications, the interface fell short in supporting the performance requirements of machine vision cameras for industrial applications. USB 2.0's relatively low throughput rate of 480 Mbps and a cable distance of just 5 meters made it impractical for the majority of industrial camera applications. Moreover, no formal standard requirements were established for USB 2.0 cameras to ensure interoperability between different software solutions and hardware components in a machine vision eco system. Consequently, USB 2.0 failed to ever achieve double digit market share adoption as a machine vision interface[1].

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1 AIA, (2013), "2013 Machine Vision Camera Study," Association for Advancing Automation, Ann Arbor, MI

Moving Forward with USB 3.0

SuperSpeed USB, also known as USB 3.0, was introduced by the USB Implementers Forum (USB-IF) in 2008 to meet the demand of higher bandwidth devices. While remaining backward compatible, USB 3.0 offers several advantages over USB 2.0:

- 10X faster throughput rate of 5 Gbps
- Sync-N-Go technology to minimize user wait-time
- Optimized power efficiency providing 5V, 900mA
- Full duplex transmission (vs. half duplex)

The first certified USB 3.0 products entered the consumer market at the Consumer Electronics Show in January 2010[2] and since then, an increasing number of manufacturers have been integrating USB 3.0 into their new products. For example, Windows® 8 was the first operating system from Microsoft supporting USB 3.0. As a result, computer and peripheral manufacturers have been gradually transitioning into this new USB interface and the machine vision market took notice.

The Machine Vision Market

Machine vision systems utilize advanced image capture and analysis technologies to help manufacturers in all industries reduce defects, increase yield and gain efficiencies in their production efforts. An upgrade from human inspection, machine vision systems can perform inspections more reliably and at faster speeds, adding efficiencies to the manufacturing process. As such, machine vision equipment systems are being deployed globally in factory automation environments.

In 2013, the total sales of machine vision components and systems from European suppliers eclipsed the previous year by 10% growth within Europe and 28% growth in Asia[3]. North American vision sales are also growing at a healthy pace, 9% in 2013 and estimated 11% for the first half of 2014[4]. A report on the "Machine Vision Market" published in September 2014 by MarketsandMarkets predicts global sales of machine vision components and systems to grow at a CAGR of 12.51% between 2014 and 2020, reaching a net worth of $9.50 billion by 2020[5].

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2 Trotter, P. (Jan 10, 2010), "First Certified USB 3.0 Products Announced", PC World, Retrieved from http://www.pcworld.com/article/186209/usb_3_0.html

3 Wendell, A. (Jul 2, 2014), " VDMA: Machine vision showing strong growth", Retrieved from http://ibv.vdma.org/article/-/articleview/4363164

4 AIA (Aug 29, 2014), " North American Machine Vision Market Posts Record First Half in 2014", Retrieved from http://www.visiononline.org/vision-resources-details.cfm/vision-resources/North-American-Machine-Vision-Market-Posts-Record-First-Halfin-2014/content_id/4993

5 MarketsandMarkets (Sep 3, 2014), "Machine Vision Market Worth $9.50 Billion by 2020," Retrieved from http://www.prnewswire.com/news-releases/machine-vision-market-worth-950-billion-by-2020-273789521.htm

Machine Vision Camera Standards

As shown in Table 1, several different interface standards exist for machine vision cameras, each with a set of pros and cons. The two main performance metrics are speed related: data throughputs (typically measured in Megabits or Gigabits per second) and frames per second (fps), which is the time between two image captures. Other considerations include color depth, additional equipment requirements such as frame grabbers, cable length and cost.

	USB 2.0	FireWire 800	GiGE VISION	CAMERA Link	USB3 VISION	CoaXPress	CAMERA Link HS
Single Cable Max Bandwidth	480 Mbps	800 Mbps	1 Gbps	2 Gbps	5 Gbps	6.25 Gbps	16.8 Gbps
Max Frame Rate for 6 MP, 14 bit Images (as example)	5 fps	9 fps	22 fps	13 fps	40 fps	70 fps	75 fps
Max Cable Length at Full Speed	5m	10m	100m	10m	3m	35m	10m
Max Distance with Extension Solutions	100m+	500m with fiber extender	5km with single-mode fiber	10m	100m with multimode fiber optic cable	400m with multimode fiber optic cable	5km with single-mode fiber
Frame Grabber Required	No	No	No	Yes	No	Yes	Yes
Total Solution Cost	$$	$$$	$	$$$$	$	$$$$	$$$$$

Table 1 - Comparison Chart of Different Camera Interfaces in Machine Vision

The **USB 2.0** and **FireWire 800** legacy interfaces are relatively inexpensive but cater to lower resolution imaging when compared to the other standards. These interfaces are in decline as the industry moves toward higher resolutions such as 1080p, 2K and 4K Ultra High Definition.

GigE Vision, released by the Automated Imaging Association (AIA) in 2006, has established itself as the top selling vision camera interface at well over 50% of new unit sales and growing[6]. GigE outperforms both legacy interfaces in bandwidth and cable distance, reaching up to 100 meters. Additionally, this technology provides networking capabilities at an affordable price.

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6 AIA, (2013), "2013 Machine Vision Camera Study," Association for Advancing Automation, Ann Arbor, MI

Camera Link is an older standard issued by the AIA in 2000 designed for high speed communication with throughputs of up to 2 Gbps. It comes in a variety of configurations using one or two proprietary cables for each camera, up to 10 meters. It is a more costly technology that also requires the use of a frame grabber (equipment that converts the video captured by the camera into a format that can be processed by the machine vision software) to communicate with the host computer, further driving up the overall system cost. Camera Link is now primarily in a maintenance mode in its product lifecycle.

Cameras with **CoaXPress** or **Camera Link HS** (superseded Camera Link) interfaces offer even greater throughputs and fps than Camera Link but are more expensive and require the use of frame grabbers. CoaXPress can support a throughput rate of up to 6.25 Gbps and long distance coverage up to 400 meters through fiber optic extension. Camera Link HS can support 2 Gbps up to distances of 10 meters. The bandwidth of both these interfaces can be further increased by using multiple off-the-shelf cables allowing for more data to transfer simultaneously through multiple channels.

Currently, a single optimum standard for all application scenarios does not exist, but the **AIA USB3 Vision™** standard comes very close. Released in January 2013 by the AIA, this standard leverages the USB 3.0 specification (with a throughput rate of 5 Gbps and plug and play simplicity without the need of a frame grabber) enabling USB 3.0 cameras to support image resolutions rivaling CoaXPress and Camera Link HS at GigE Vision type pricing.

The USB 3.0 cable distance limitation of approximately 3 meters is often an issue when USB 3.0 cameras and the host computer cannot be in close proximity to each other. Thankfully, there are affordable extension solutions to address this limitation, allowing USB 3.0 to be reliably extended up to 15 meters over copper and up to 100 meters over fiber. Please refer to Icron's white paper *Extending USB 3.0 Camera Operation in Machine Vision Applications with ExtremeUSB® Technology* (document # 90-01318) for more information on this subject matter.

Today, with sales growth rates on the rise, USB 3.0 cameras are offered by most major machine vision camera manufacturers. Many industry analysts expect the usage of FireWire and USB 2.0 cameras to decline rapidly in the machine vision industry and be replaced by USB 3.0[7]. Due to its attractive blend of speed, fps, affordability, ease-of-use and availability of extension solutions, USB 3.0 is widely expected to become positioned as the second largest machine vision camera interface behind GigE Vision[8] over the next couple of years.

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7 Blackman, G. (April/May 2012) "Setting standards," Imaging and Machine Vision Europe, Retrieved from http://www.imveurope.com/features/feature.php?feature_id=190

8 Carroll, J. (October 9, 2014) "GigE and USB 3.0 identified as top interfaces in Vision Systems Design poll," Vision Systems Design, Retrieved from http://www.vision-systems.com/articles/2014/10/gige-and-usb-3-0-identified-as-top-interfaces-in-vision-systems-design-poll.html?cmpid=EnlVSDJanuary192015

Summary

For machine vision applications, there are several camera interfaces to select from at varying price points; each comes with its own advantages and disadvantages.

Some interfaces, such as Firewire and USB 2.0 are becoming obsolete due to their inability to support customer demand for higher resolution images and faster frame rates. The USB 2.0 camera interface was not widely adopted in machine vision because of its low throughput of 480 Mbps and a distance limitation of 5 meters. In addition, no standards were created to regulate and promote interoperability between different software and hardware components, creating total solution installation headaches.

USB 3.0 overcame the limitations of USB 2.0 with throughputs of 5 Gbps and provides the necessary bandwidth to support today's performance requirements for higher resolution and more frames per second. By means of a standards governing body (through the publication of the AIA USB3 Vision™ specification) and the ability to increase operational distance beyond 3 meters with affordable extension solutions, it is easy to understand why USB 3.0 adoption is on the rise and well poised to become a dominant interface standard for the machine vision industry.

About Icron Technologies Corporation

Icron Technologies is a leading developer and manufacturer of high-performance USB and video extension solutions for commercial and industrial markets worldwide. Icron's patented extension technology extends Video and USB devices over many media types including Cat 5e, Fiber, Wireless, DisplayPort®, and over a corporate LAN. Icron's extension products are deployed in a wide range of applications including pro AV, industrial automation, machine vision, medical imaging, aerospace, interactive whiteboards, remote desktop extension, security, enterprise computing and isolated USB, or anywhere a PC needs to be remotely located from a display or peripheral device.

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Extending Connections™

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