Technical Paper

ALACRON

THE PROS AND CONS OF USB2.0

INTRODUCTION

As an executive running a frame grabber manufacturing company I recently decided to examine the pros and cons of the new emerging interface protocols, i.e. USB2.0, IEEE1394, and Camera link, and the impact they will have on the frame grabbers and machine vision markets. Standardization of peripheral buses (spurred by OEM PC manufacturers to enable the public to easily add peripherals, including machine vision cameras, to their PCs without expert assistance) has had an invigorating effect on the choice of camera interfaces. This has been further accelerated by the rapidly increasing CPU and memory data rates, which present an increasing option of native PC-based real or near real time processing.

Users buying cameras to meet specific applications and speed requirements, generally consider system price and ease of integration as primary factors in making their choices. Similar factors influence systems integrators, who have to provide application solutions at competitive prices. Thus, the kind of interface implemented is not usually as important to the camera user as is the price, the availability of many vendors, the available suitable technology, and the ease of integration. Thus I will present the results of my analysis from the standpoint of markets and its potential and outline why I came to the conclusion that USB2.0 is a very attractive choice for a specific large segment of the machine vision market.

CAMERA INTERFACES

We will review the history and features of USB2.0 and briefly the common machine vision interfaces so as to provide a basis for the discussion of the Pros and Cons of USB2.0, which is to follow.

USB 2.0

USB BACKGROUND

The Universal Serial Bus (USB) standard was originally developed in 1995, to minimize the number of ports in the back of the PC. The major goal of USB was to define an external expansion bus, which makes adding peripherals to a PC. USB2.0 is the 2000 update of the original USB1.1 standard approved and incorporated into most PC chassis. The USB 2.0 specification extends the maximum speed of the connection from 12 Megabits per second (Mbps) for USB 1.1 up to 480 Mbps (60MBytes/sec). This enables the real-time transfer for high-definition video conferencing or 320x240 images at 500 fps for high-speed video motion analysis. This interface will also provide bi-directional serial communication for camera setup and control, triggering, strobing and other I/O signaling. T

The USB1.1 and 2.0 connectors and cables are the same 5 Meter cable length between devices. A peripheral can either be self-powered or bus-powered, with up to 500mA of consumption.

USB INITIATION AND PROTOCOL

A USB device can be plugged in anytime. A high-speed camera initially attaches to the PC USB controller as a full-speed usb1.1 device. The camera then signals it is high-speed capable. The host controller responds to indicate it is also USB 2.0 capable and begin communicating at the high-speed

rate. The PC then learns the devices capabilities, by requesting its "descriptors". This information is stored within the power and bandwidth needs and required driver. From this information, the PC automatically loads the device's driver into the operating system and the device is ready for use. This sign-on process is called

Enumeration.

In USB, the PC is the master and the peripherals are slaves. The PC makes requests and peripherals respond. For maximum bandwidth utilization, up to 13 packets containing 512 bytes of data can be transferred during each micro frame in isochronous mode. This translates to a of over 53 Mbytes/sec

USB Vendor Support

Intel has released a family of chipsets starting with the 845 the Pentium-4 based family of processors. These chipsets, which include the ICH4 South Bridge chip, all have an embedded USB2.0 enhanced host controller interface and hub, capable of supporting up to 6 high or low speed ports. Similar support chips for the AMD processors and other bridge manufactures also incorporate the USB2.0 standard into their silicon. Further accelerating market domination, more than 80% of the new motherboards have USB2.0

Since the ICH4 connects directly to the memory controller, (a.k.a. North Bridge chip), over a 266MB/s (32bit/66MHz) hub interface, it can simultaneously move data from the USB2.0 at maximum rates without reducing the bandwidth capacity of the 32bit/33MHz PCI bus. Thus additional USB2.0 PCI adaptor cards can be added into the system without affecting the **bus.**

USB Software Support

Microsoft has released a driver for Windows XP and has upgrades planned for Windows ME and Windows 2000. However, Microsoft has stated it will not provide USB 2.0 driver support on Windows 9x or earlier Windows operating systems. Adaptec, a recognized leader in USB2.0 Adaptor cards and hubs, has jumped in to fill this market need by developing and delivering drivers for their USB2.0 host products for WIN 98, XP, ME and 2000. The Linux community has even recognized the imminent growth of USB2.0 and has already released driver support in their latest kernel.

USB 2.0 ON-THE-GO (OTG)

Due to the growing need for a direct interconnectivity between devices the USB 2.0 specification was recently supplemented with "On-The-Go" (OTG). An OTG peripheral will have limited host capability and enable direct data transfer, peer-to-peer, to another USB or OTG peripheral, without the PC.

USB Camera Vendors

Silicon Imaging (www.siliconimaging.com) has the SI-3200. The SI-3200 is a 3.2 mega pixel USB 2.0 camera, capable of 2048x1536 at 12fps or 1920x1080 HDTV resolution at 24fps using the USB2.0 as a camera interface. T he SI-320F can capture and recording 320x240 resolution video at over 350 frames per second for high-speed motion capture and sports analysis. For scientific analysis, medical imaging and stop-motion machine vision applications the SI-1024F has 1024x1024 resolution up to 30fps with large 12um pixels, full-frame shutter, binning, adaptive readout and windowing. Lumenera (www.lumenera.com) offers the Lu120, a mega pixel camera capable of 1280X1024 pixels at 16 fps or 640X480 at 60 fps using USB2.0. Another vendor, Opteon (www.opteontech.com), offers modular

cameras with a wide variety of interfaces including USB2.0. The cameras discussed so far all use USB2.0 as the primary interface. Another approach is taken by FastVision (www.fast-vision.com) where their high-speed "smart" CMOS cameras, FastCamera40 and FastCamera13, use USB2.0 as a 30-40 Mbytes/sec secondary video port or to download the results of the in-camera-processed image or data. This list is not meant to be exhaustive but rather present some indication of the capabilities of the USB2.0 interface for machine vision applications.

IEEE1394 (Firewire, I-Link)

Products supporting the 1394a standard go under different names, depending on the company. Apple, which originally developed the technology, uses the trademarked name FireWire. Other companies use other names, such as i.link and Lynx, to describe their 1394 products. 1394a also supports isochronous data, which guarantees bandwidth. This makes it ideal for devices that need to transfer high levels of data in real-time, such as video devices.

An upgrade of 1394a to 1394b with data rates in excess of 800Mbit/sec has been defined. IEEE 1394b allows extensions to 800Mbit/sec over copper wire. The improved speed and distance capabilities of 1394b result from two major improvements: overlapped arbitration and advanced data encoding. The 1394b standard provides significant amounts of bus power (up to 25 watts). It generally l requires a custom interface card since most motherboards except Apple's G5 do not support it. The add-in card requires a 66mhz 64-bit interface since otherwise the data will immediately saturate the 32/33Mhz PCI bus.

Gigabit Ethernet (802.3ab)

Gigabit Ethernet is the natural 1000 Mbits/sec extension of either Fast Ethernet (100 Mbits/s, 100 Base T) or Ethernet (10 Mbits/s, 10 Base T). The familiar Cat5 copper interface is called 802.3ab for single C at5 interconnection and 802.3T (1000 baste T) for the configuration using four Cat5 cables for connection. The result extends the range of CAT5 from 25 m to 100m. There is no isochronous mode for Ethernet, however if one uses a point-to-point data transfer, approx 900Mbit/sec rates can be achieved using a 66 Mhz 64 bit PCI interface board with a typical bandwidth of 500-700 more usual.

CAMERA LINK

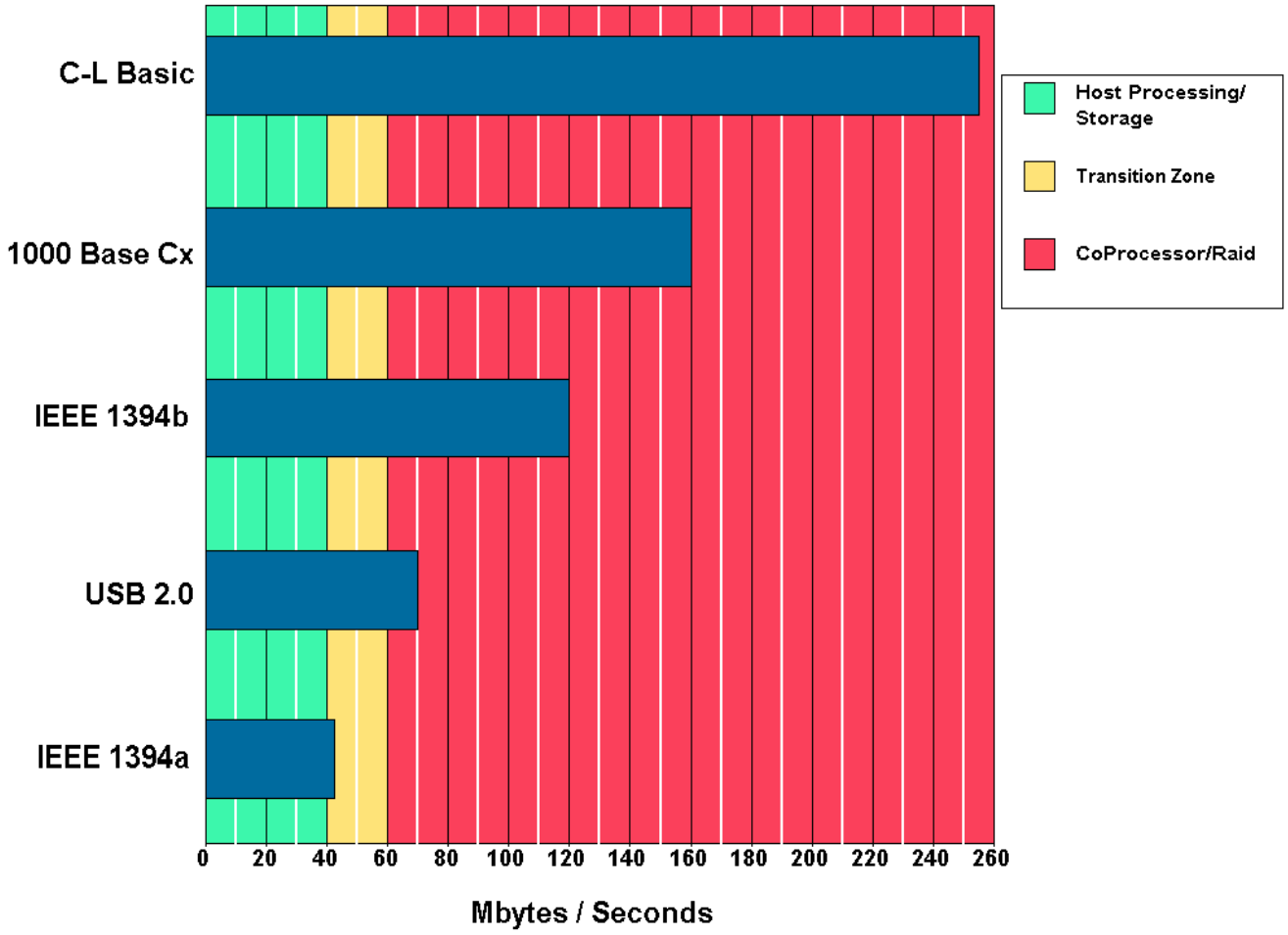
Camera Link is an interface standard originated by Pulnix and recently transferred to the AIA. The Camera Link standard is based on National Semiconductor's inexpensive Channel Link technology, which has transmission rates of up to 2.38 Gbits/s (297.5 Mbytes/s) per channel. With a standard connector and pin-outs, Camera Link, as currently defined, uses one to three channels (Base, Medium, or Full configurations, with an extension proposed by Basler Vision Technologies, www.baslerweb.com), depending on video data format and rate.

INTERFACE COMPARISONS

The table below shows the most important feature of the various protocols in tabular form for easy comparison. USB2.0 is clearly competitive with the other camera interface with adequate speed, virtually universal hardware and software support and low cost.

CATEGORY	*IEEE-1394a*	*USB 2.0*	*IEEE-1394B*	*GIGABIT ETHERNET (802.3AB)*	*CAMERA LINK BASIC*
TOPOLOGY	**Peer-to-peer**	**Master-slave, OTG**	**Peer-to-peer**	**Networked, P2P**	**Master-slave**
MAXIMUM BIT RATE	**400 Mbits/s**	**480 Mbits/s**	**800 Mbits/s**	**1000 Mbits/s**	**2000 Mbits/s,**
ISOCHRONOUS MODE	**Yes**	**Yes**	**Yes**	**No**	**Yes**
MAXIMUM SUSTAINED BIT RATE (P2P)	**320 Mbits/sec (80%)**	**432 Mbits/sec (%90)**	**640 Mbits/sec (%80)**	**930 Mbits/sec**	
CABLE DISTANCE COPPER	**4.5 M**	**5 M**	**100 M**	**25 M**	**10 M**
BUS POWER	**Up to 1.5A**	**Up to 0.5A**	**Up to 1.5 A**	**None**	**None**
MOTHERBOARD SUPPORT	**Some, usually non-Intel**	**Virtually all**	**Some, usually non-Intel**	**Some**	**None**
ADD-IN BOARD COST	**$40 US**	**$30 US**	**$80**	**$80-250 US**	**$500-1000 US**
OS SUPPORT	**Windows, Linux**	**Windows, Linux**	**Windows, Linux**	**Windows, Linux**	**Depends on vendor**
MAIN APPLICATIONS	**Consumer electronics**	**PC-centric serial input**	**Consumer electronics**	**Networking**	**High speed camera interface**

The graph below illustrates the relative speed of the interfaces. Current host (native) solution depending on the host processor and disk interfaces to handle the processing or storage of the image data streams in real-time usually peak out at 240-320 Mbits/sec (30-40 Mbytes/sec). Thus USB2.0 is adequate for these applications, which constitute the bulk (numerical) of machine vision applications. When one exceeds 400-480 Mbits/sec (50-60 Mbytes/sec) either a coprocessor or more expensive disk array system is needed to process or store the data in real-time. Thus the system cost and complexity significantly rises for these applications and hence constitute a more expensive, numerically inferior segment of the machine vision market.



CONCLUSIONS

Experience dictates that transitions to new technology work best if they provide significant user benefits, standards compatibility, industry support, transparency, and cost effectiveness. Let's see how USB 2.0 stacks up in these areas.

PROs

USB 2.0 is fast. Most machine vision cameras used for real-time native processing applications or storage need bandwidth somewhere between 200Mbit/sec. and 320Mbit/sec., so USB 2.0's 480Mbit/sec. provides full bandwidth.

Despite the 40-times increase in bandwidth, USB 2.0 is still a simple "user obvious" technology using inexpensive connectors with easy installation via plug-and-play. Only one connector style is needed for the entire PC system, the simplest system of any of the competitors.

With Intel and other chipset manufacturers integrating USB 2.0 host controllers into chipsets, the system costs of implementing USB 2.0 will be incremental vs. the cost of adding a discrete host controller for something like 1394. Thus USB 2.0 is the preferred connection for most PC peripherals, and is currently on virtually all Pentium and Athlon system boards. Apple has even installed USB2.0 along with IEEE1394b on their new G5 machine. The IEEE 1394 interface will continue to coexist with USB2.0 in

the audio/visual consumer electronic devices because of the clear support of Sony's camera line for the IEEE1394a interface.

Extremely since most system motherboards have built-in USB2.0. Fewer chipsets support IEEE1394a or Gigabit Ethernet 802.3ab. No motherboard supports Camera Link. Add-in boards for USB2.0 are similarly priced from $30 US.

CONs

Currently there are no initiatives to upgrade the speed of USB beyond 480 Mbits/sec. This is unlike the situation with the IEEE1394 standard, which has definitions for 1600 and 3200 Mbits/sec extensions. Similarly, 10Gbit Ethernet is already supported by silicon, and Camera link can be extended to medium, full and the extended specification using 80 bits running at 85 Mhz, i.e. 6800 Mbits/sec. Thus if the upgrade path or potential upgrade path is important to the project, then USB2.0 solution is problematic.

So far there is growing support for the USB2.0 interface in the machine vision community, but since USB2.0 is relatively recent, the support trails that of IEEE1394a and Camera Link. This should change as time passes for the reasons outlined in the Pros above and our experience with the relatively slow adoption of the IEEE1394a standard outside of Sony. It should also be noted that IEEE1394b and 1000 Base-CX have less clear camera support at present than USB2.0

No other technology meets as many of the criteria listed above, so this is why the USB 2.0 support is appearing so fast. With millions of powerful 2.4 to 3.0GHz motherboards with USB 2.0 built-in to ship this year, with no additional cost to the user, there is no doubt that USB2.0 will soon become the de-facto standard for host vision cameras and high speed image processing. USB 2.0 will be the preferred connection for most PC peripherals, whereas the IEEE 1394 interface will coexist with USB2.0 in audio/visual consumer electronic devices. The USB2.0 will achieve faster speeds and lower costs than IEEE-1394. However, Camera Link will continue to be king of speed. For the vision system end-user, the benefit will be a lower system cost than previous camera and frame grabber solutions and plug-n-play installation.

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