Choosing the Right Camera Bus

Machine vision acquisition architectures come in many different forms, but they all have the same end goal –to transfer image data from a physical sensor into a processing unit that can analyze the image and take an action. This goal is the same for PC-based machine vision systems, embedded compact vision systems, and smart cameras.
Of these architectures, PC-based machine vision systems are the most popular because they provide the best performance and the most flexibility for the price. With that said, all physical architectures have the same starting point and ending point. You have a camera on one end and a processing unit on the other. This white paper explores the strengths and weaknesses of the five major camera buses – analog, Camera Link, USB, IEEE 1394, and GigE Vision – and describes the decisions and trade-offs you may need to make when deciding which camera bus is right for your application.
This white paper compares the five camera buses over the following eight categories on a relative scale:
1. **Throughput –** The rate at which image data can be transferred over the bus.
2. **Effective cost –** The overall component price of a system, including the camera, cables, frame grabbers, and software.
3. **Cable length –** The maximum possible distance between the camera and the PC without repeaters.
4. **Standardized interface –** A measure of ease of use and future scalability. Plug-and-play interfaces make some camera buses easier to use and allow for future system upgrades without significant rework.
5. **Power over cable –** The ability of the camera bus to provide power to the camera over the same cable.
6. **Camera availability –** A measure of the number of different camera types available, how long the camera bus has been available, and the overall acceptance of the standard in the vision industry.
7. **CPU usage –** The amount of CPU available to process images during image acquisition.
8. **I/O synchronization –** The ease at which triggering and overall system communication is addressed and handled within the camera bus.

In this white paper, each camera bus receives a relative score from one to five for each of the eight categories above, where five is the highest score and one is the lowest. Because there is not a dominant bus for every application, the relative scores are represented in a "spider graph." With these graphs, you can rank the camera buses yourself depending on which category is most important to you.

Gigabit Ethernet is a new camera bus technology for machine vision systems. With relatively high bandwidth, long cable lengths, and wide usage in the consumer and industrial applications, Gigabit Ethernet shows promise for security and long-distance vision applications. Unlike USB and IEEE 1394, Ethernet was not originally intended to connect peripherals. Ethernet does not offer plug-and playnotification. Device discovery requires additional protocols or user intervention. These shortcomings are addressed in the new GigE Vision standard from the Automated Imaging Association (explained below).

Throughput: The theoretical maximum bandwidth of Gigabit Ethernet is 125 MB/s. With hardware limitations and software overhead, the practical maximum bandwidth is closer to 100 MB/s. This bandwidth is the same as IEEE 1394b and is second only to Camera Link. **Score: 3**

Cost-effectiveness: The overall system cost of GigE Vision is very similar to IEEE 1394. The cameras may be slightly more expensive, but the cabling is cheaper. Neither requires a frame grabber. **Score: 4**

Cable length: Cable length is truly where GigE Vision excels. With cable lengths reaching 100 m, GigE Vision is the first camera bus to rival analog in terms of cable length. This characteristic has helped GigE Vision replace analog in security and monitoring applications. **Score: 5**

Standardized interface: Recently, the Automated Imaging Association along with several member companies defined an in-depth industrial camera standard built on top of Gigabit Ethernet called GigE Vision. The GigE Vision standard overcomes some of the shortcomings of Gigabit Ethernet by providing plug-and-play behavior, device discovery, error handling, and secure image transfer.
The GigE Vision standard provides a level of standardization that is on the same level as IEEE 1394 in terms of ease of use and hardware scalability. **Score: 5**

Power over cable: One major drawback of GigE Vision is the inability to power the camera over the Ethernet cable. This means that every GigE Vision camera requires its own, separate power supply. **Score: 1**

Camera availability: The GigE Vision standard, completed in April 2006, is currently gaining acceptance in the industry. It may take several years before the breadth and availability of cameras reaches that of IEEE 1394. **Score: 2**

CPU usage: Different software implementations of the GigE Vision standard yield very different CPU loads. In general, there are two types of drivers for acquiring images from GigE Vision cameras: filtered and optimized. Filter drivers separate incoming image data packets from other traffic on the network at a high level. They are easier to create and use but make heavy use of the system
CPU. Optimized drivers written specifically for a dedicated network interface card (NIC) work at a much lower level. For instance, by writing an optimized driver for an Intel NIC, packets containing image data can be separated at the NIC instead of the CPU. These optimized drivers use very little of the CPU and are essential for image processing applications that are processor-intensive. **Score:**
2

I/O synchronization: Because GigE Vision applications often make use of the long distances between the PC and the camera, triggering and communication are a little more challenging than with IEEE 1394. Oftentimes with IEEE 1394, a proximity sensor is connected to the PC that then triggers the camera with a known pulse. However, with Ethernet distances up to 100 m, it is more
difficult to use the PC to condition a trigger signal between a proximity sensor and the GigE Vision camera. **Score: 2**