Introduction

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.

Analog Camera Buses

Industrial analog cameras use coaxial cable to transmit an analog video signal from the camera to an image acquisition device or monitor. The analog video signal transmitted by the camera uses the same composite video formats that TV stations use to broadcast video signals around the world. The two main video standards for color video signals are the National Television Systems Committee (NTSC) and Phase Alternative Line (PAL). NTSC is more common in North America and Japan, and PAL is more common in Europe. For monochrome video signals, the two main video standards are the Electronic Industries Association (EIA) RS170 and Consultative Committee for International Radio (CCIR). RS170 is common in North America and CCIR is common in Europe.

Throughput: Analog cameras are suitable for low- to medium-bandwidth imaging applications. Pixel clock rates are usually less than 40 MHz, and most analog cameras transmit only one pixel per clock cycle. While exceptions exist, the vast majority of analog cameras follow one of the four major video standards described above. The largest throughput exists under the PAL standard, which transmits data at a little more than 11 MB/s. While this rate is acceptable for many vision applications, it is the lowest of the five major buses. **Score: 1**

Standard	**Type**	**Frame Size (pixels)**	**Frame Rate (frames/s)**	**Line Rate (lines/s)**
NTSC	Color	640 by 480	29.97	15,734
PAL	Color	768 by 576	25.00	15,625
RS170	Black and white	640 by 480	30.00	15,750
CCIR	Black and white	768 by 576	25.00	15,625

Cost-effectiveness: Because analog cameras have been around for half a century, they are inexpensive. However, this low cost is often offset by the need for an image acquisition board inside the PC, also known as a frame grabber, to convert the image into a digital representation and send it to system memory. While the cost of analog frame grabbers has also fallen over the years, the total system cost is still more than with other camera buses. **Score: 3**

Cable length: Analog camera cabling ranges from simple to complex. The most basic video connection to a standard analog camera requires only a single 75 Ω coaxial cable, often with standard BNC connectors. Nonstandard analog cameras sometimes require additional lines to carry the horizontal and vertical synchronization signals. The recommended maximum cable length for analog video signals varies widely. Some sources suggest a length of 10 m or less for the best video quality, while other sources, particularly in security or broadcast video, say that runs of 100 m or more are acceptable with minimal loss in image quality. **Score: 4**

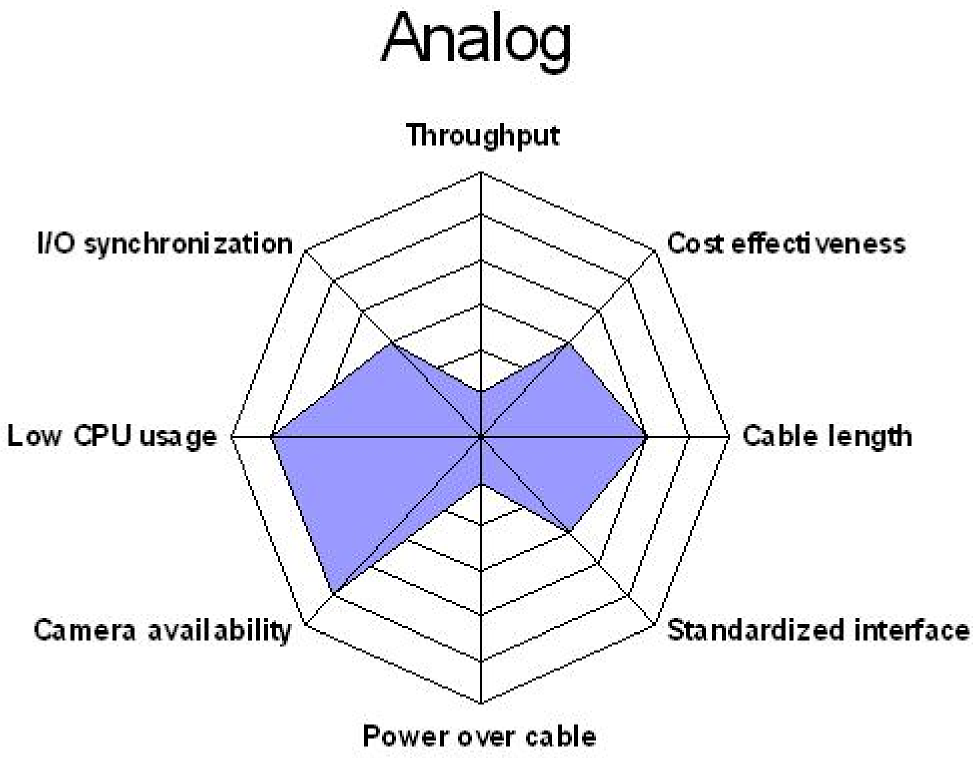
Standardized interface: Even though analog standards have existed for decades, the introduction of nonstandard analog cameras is more complicated because it requires additional horizontal and vertical synch signals. When compared to other camera buses that feature automatic camera discovery, digital image quality, and software camera configuration, analog camera buses leave much to be desired. **Score: 3**

Power over cable: Analog camera buses provide no means of powering a camera. Because of this, every analog camera needs an external power supply, usually 12 V. **Score: 1**

Camera availability: This is the strongest category for analog cameras and the reason why they continue to be successfully sold for machine vision applications. Because the technology is well-established and understood, it is very easy to find and use analog cameras. In fact, most consumer video recorders still have analog NTSC or PAL outputs on them. **Score: 5**

CPU usage: Analog cameras must plug into some sort of frame grabber to convert the image signal from analog to digital. These frame grabbers can also transfer the image data to memory using DMA channels that do not burden the computer's CPU. Because of this, analog image acquisition uses very little of the system CPU. **Score: 5**

I/O synchronization: Some analog cameras designed for machine vision have features such as asynchronous reset and additional I/O lines. On top of this, because analog cameras require a frame grabber, there are often plenty of I/O lines for triggering and communication from the PC. On the down side, the analog camera buses do not provide any standard form of communication for setting camera features, such as exposure time, gain, or shutter speed. These features usually have to be set with DIP switches. **Score: 3**



Section 3: Camera Link