WHITE PAPER

Camera Interfaces and PC Cards for Multi-Camera Systems in Comparison

Content

1. Camera Interfaces for Multi-Camera Systems

When using cameras together with PC cards, users can choose between several camera interfaces. The most important of these are USB 3.0, CXP 2.0 and Gigabit Ethernet (GigE). Each of these interfaces has its own advantages and disadvantages, which can justify the respective selection depending on the application area and usage scenario. This white paper examines these advantages and disadvantages with regard to multi-camera systems; it also defines the most advantageous interface for such systems, and additionally discusses PC cards as the most important component in a multi-camera system. These PC cards form the interface to the camera used, are installed in the PC for smooth image acquisition and transmission, and thus digitize the analog camera signals.

1.1 CoaXPress 2.0

CoaXPress (CXP) has become a new standard in industrial image processing in recent years. If users decide to use the CoaXPress interface, which was published in 2008 and has now been established for over ten years, the use of a CXP-12 interface card or a CXP-12 frame grabber is automatically required. The difference lies in the price and the technical design. The frame grabber is technically more sophisticated, because it contains, for example, pre-processing and other image processing features. For many applications, even with several cameras, a cheaper interface card is often sufficient.

The use of the CXP interface is optimal for applications that require high speed or resolution and real-time behavior; CoaXPress 2.0 can achieve high data rates and low latency. With high-speed interfaces such as CoaXPress 2.0, users can take full advantage of the capabilities of modern image sensors and achieve maximum performance in their applications. Advantages and disadvantages of this interface at a glance:

Advantages:

- Plug and play connectivity of CoaXPress components combined with very high bandwidth (12.5 Gbps per channel).
- Cable lengths of up to 40 meters are possible with high bandwidth, and at low bandwidth even over 100 meters.
- Data transmission as well as power supply can be achieved via coaxial cable (single cable solution) to establish the connection between camera and PC.
- By combining frame grabber technology with the cameras used, very precise camera synchronization is possible even in multi-camera systems (limited to 4 cameras) with very low latency.

Disadvantages:

- Individual components required for this interface technology, such as the frame grabber, are more cost-intensive compared to the USB 3.0 and GigE interface, which can make the entire system more expensive.
- CXP cameras are less compact: Compared to

compact USB 3.0 or GigE cameras, they tend to be larger. This is partly due to the larger built-in sensors, which operate at very high speeds and therefore generate more heat

1.2 USB 3.0

Launched in early 2013, the USB3 Vision standard defines all necessary elements that make USB 3.0 suitable for industrial image processing applications. Besides connectors and cable characteristics, it describes the communication between a USB 3.0 device and USB 3.0 compliant software. Since USB 3.0 has become a widespread standard in the consumer market, the majority of hardware supports USB 3.0. Advantages and disadvantages of this interface at a glance:

Advantages:

- High bandwidths of over 350 MBps
- No additional cost for a separate frame grabber
- Plug-and-play, which allows more flexibility, especially for applications based on different PC setups
- USB 3.0 hardware is widely available: most new devices--from PCs to the smallest PC cards--have USB 3.0 embedded connections
- Low CPU load
- USB3 Vision standard
- Cost efficiency

Disadvantages:

- Multi-camera systems are possible, but the maximum bandwidth is limited by the individual cameras. This makes complex multi-camera systems with more than four cameras difficult to implement.
- Short cable lengths up to 8 meters

1.3 GigE Vision

Gigabit Ethernet (GigE) has been an established standard in industrial image processing since 2006. Measured by the number of installed applications, it is currently the fastest growing interface technology for industrial cameras. Gigabit Ethernet owes its popularity to its ability to solve some key problems effectively. Restrictions in cable lengths, which were common with older interfaces, are no problem with Gigabit Ethernet, which is advantageous for multi-camera systems.

In addition, the combination of several cameras with one PC is much easier and more cost-effective. As well, this interface technology is widely used in traditional IT, which means that there is a wealth of know-how on this technology as well as standard components. Gigabit Ethernet already dominates numerous areas of image processing, from production to intelligent traffic systems, in which multi-camera systems are often used. Advantages and disadvantages of this interface at a glance:

Advantages:

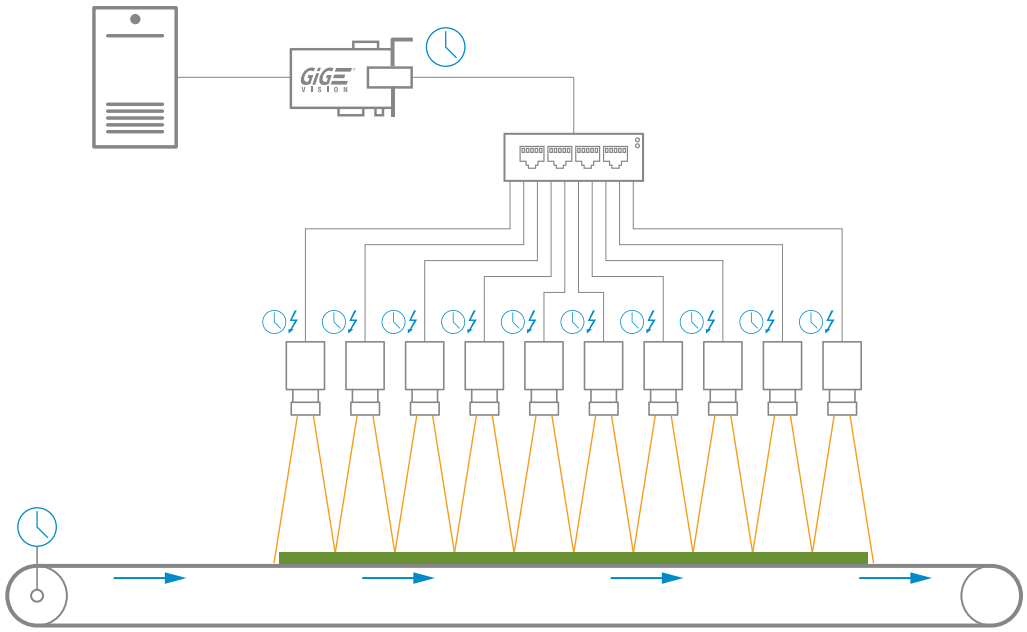
- Simple infrastructure and minimal hardware requirements for multi-camera systems
- Data transfer rates from 1 Gbps up to 10 Gbps
- Scalability for future higher requirements
- Maximum cable lengths of up to 100 meters as well as single-cable solutions via Power over Ethernet (PoE) possible; expandable by connecting additional network components (e.g. switches)
- Cameras can be operated synchronously and/or in real-time without additional cabling via Precision Time Protocol (PTP)
- Framegrabber is not required
- GigE Vision standard
- Cost efficiency

Disadvantages:

- The CPU load required for image acquisition is typically about 10 to 15%; however, this can be minimized to 3 to 8% CPU load when using drivers and settings optimized for machine vision.

2. Possible Combinations with GigE Vision

Of the three interface technologies presented, the GigE Vision interface is usually the most suitable technology for multi-camera systems due to the simpler infrastructure, maximum cable lengths and cost efficiency. To use multiple cameras, however, PC cards are required that have the appropriate number of ports and represent the appropriate data transfer rate. Since a conventional PC often has only one GigE port, which is usually occupied for machine control, these cards are indispensable for such a scenario. In addition, machine vision cameras require the full bandwidth of the port to which they are connected. Coupling several cameras via a distributor (usually switches) to the port available on the PC therefore fails due to the bandwidth of the port. The above-mentioned PC cards, which also allow a higher bandwidth at one port, provide a solution.



Accordingly, GigE interface cards with 1 Gbit and 1, 2 or 4 ports are usually used as PC cards for machine vision. In very rare cases, it is possible for users to use interface cards that provide even more ports. Thus, a single interface card can reduce the system complexity immensely by eliminating additional network components that can cause system errors. In addition, the PoE function makes it possible to implement a single cable solution, eliminating the need for a „complicated" power supply for the application. Thus, the system is as easy to handle as a USB camera setup and has the additional advantages of the GigE interface.

In addition to the 1 Gbit interface cards, 10 Gbit interface cards are also available on the market, making it possible, for example, to operate ten 1 Gbit cameras at full bandwidth, i.e. at full speed. By connecting a switch it is even possible to create a camera setup with more than ten cameras. Furthermore, industrial camera manufacturers are already increasingly using fast interface technologies and will do so even more in the near future. Such cameras with more than 1 Gbit can be used with corresponding 10 Gbit interface cards, allowing the full performance of the cameras to be utilized. Since there are currently no 5 Gbit interface cards available that meet the machine vision requirements, users in most cases use a 10 Gbit interface card for this scenario, which must be backward compatible. However, this is not a real drawback, since a 10 Gbit interface card with two ports allows, for example, multiple GigE cameras to be used at full performance.

3. Application Scenarios

Different scenarios are possible when using GigE cameras in a multi-camera setup. On the one hand, in an application with one to four cameras, trigger cables can be used to supply power to the camera, which means that a PoE function of the interface cards is no longer absolutely necessary. On the other hand, if five to eight cameras are used, triggering is controlled via the software and thus the PoE function of the interface cards is used, so that only one cable is required to supply power to the camera. Triggering via the software can of course also be used with less than four cameras. However, since the system complexity in this setup is low, users usually use additional trigger cables and do not need the PoE function.

If a 10GigE interface card with one port and a 10GigE switch are combined, up to ten 1 Gbit cameras can be used. Analogously, this also works with a 10GigE interface card with two ports to connect up to 20 cameras. The following chapter shows that these previously described application scenarios do not only work in theory, but are actually implemented by users and are therefore common practice.

4. Use Cases

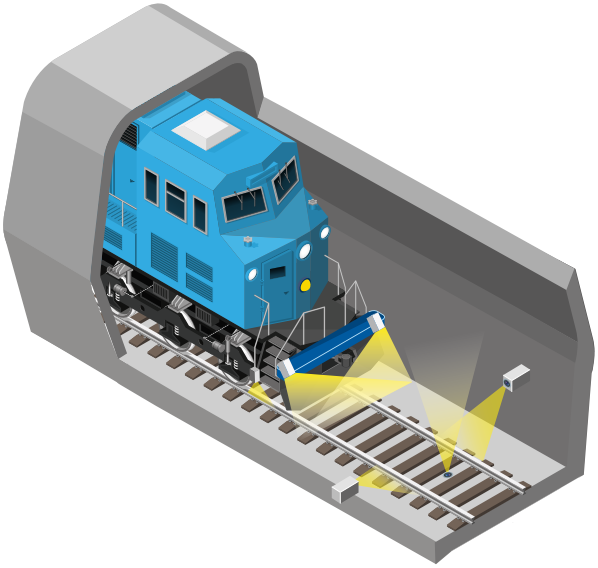
In many camera applications, it is often necessary to use multiple cameras to acquire images, such as in 3D triangulation, sports and motion applications, quality inspection and assembly line applications. When capturing a goal shot in a soccer game, it can be crucial to capture multiple images at precisely defined points in time.

4.1 Railway Inspection

The regular inspection of railroad tracks is crucial to ensure the safety of rail traffic. Among the many inspection techniques used by modern railroad companies, ultrasonic inspection based on a recorded image of a rail is a particularly good and promising method. The inspection vehicle that carries out the inspection is equipped with four GigE cameras to inspect the rail from the top and side surface and thus check for defects.

A multi-camera setup is also used to carry out quality control of trains and thus check the individual wagons and wheels of a moving train for defects. In this application example, freight trains travel along the track at 50 to 60 km/h and are inspected for defects by three GigE cameras: one camera mounted on the rail bed and two more beside the rail. The captured images of the undercarriage and wheels are transmitted to a control room

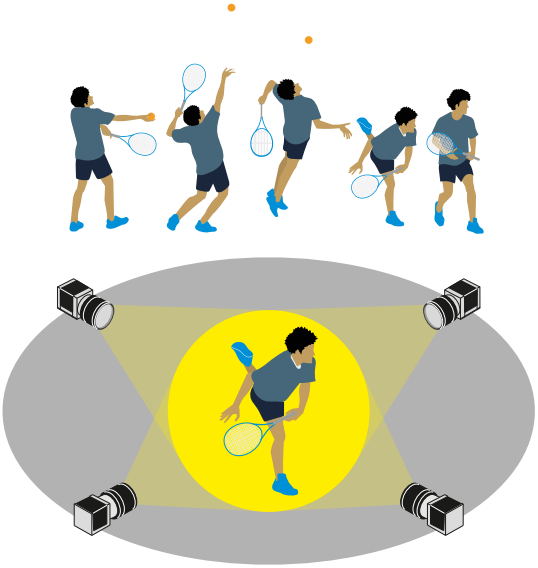
where experts carefully examine the images for defects and flaws. A decisive factor in the use of cameras with GigE interface was capability for long cables, which ensure easy connection between the inspection system and the control room.



4.2 Sports Applications

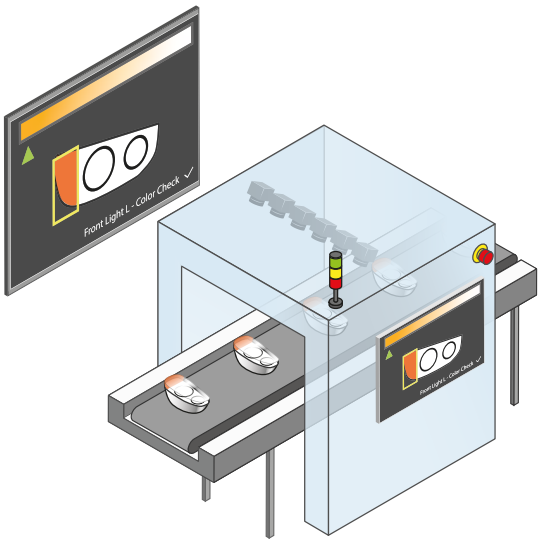
A camera-based, computerized tennis analysis system helps tennis players of all levels to improve their game. The system uses five cameras to digitally record every aspect of the game or training session. The cameras capture and record every movement of the ball and players and automatically classify each shot.

A powerful video and statistical analysis program specifically designed for professional soccer uses three GigE cameras that capture every inch of the field. Proprietary software then seamlessly combines the three images into a single, high-resolution, real-time view of the field from corner flag to corner flag. The result is an ultra-high-resolution video that covers the entire field and includes a pan and zoom function to give users complete control over the displayed video.



4.3 Assembly Line Application

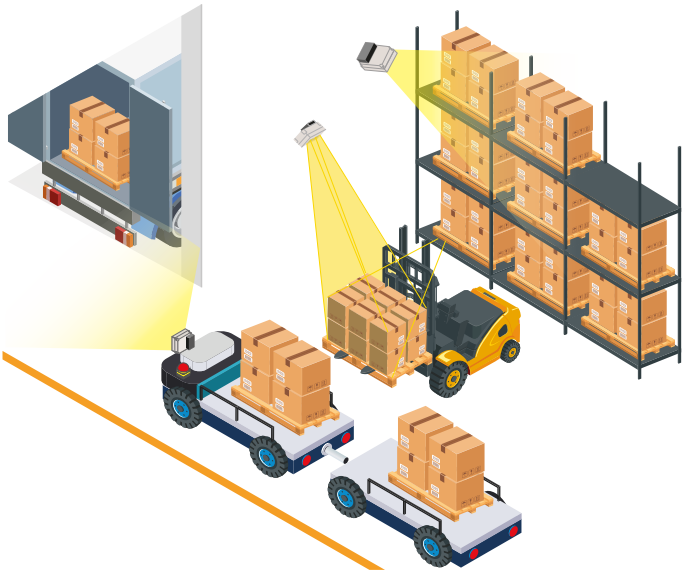
In this automotive application, software analyzes the images, checks the dimensions of the objects and ensures that all the necessary components are present. The inspection environment consists of a black room or cabinet in which walls, floor and ceiling are equipped with dozens (up to 100) GigE cameras. The inspected object, such as a front frame, is brought from the production line into the cabinet. There the cameras record the object from all sides using the optimally designed lighting in the cabinet.



Since each camera and each segment of the LED illumination performs its task according to a precisely defined cycle, the imaging process takes only a few seconds. A Power-over-Ethernet interface reduces the number of cables required and simplifies maintenance and installation. Via GigE transmission, several dozen cameras are controlled by a single software component. Fast electronic shutter speeds, programmable down to a fraction of a second, enable effective imaging applications on a fast-moving production line.

4.4 Logistics

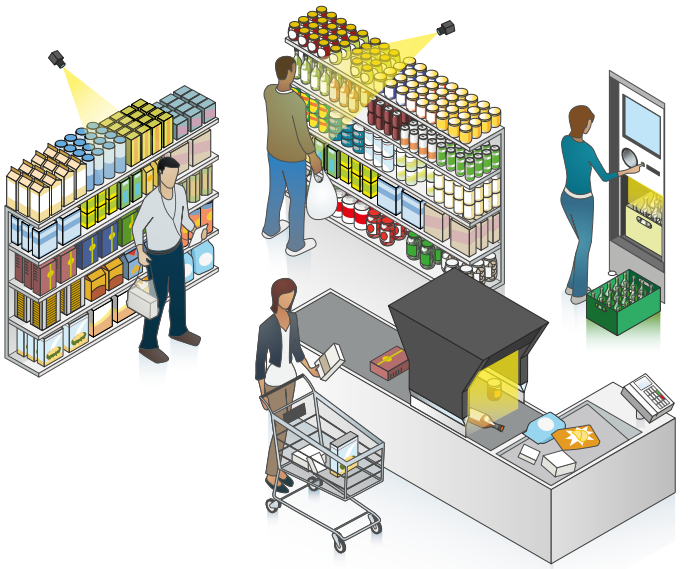
In times of Internet trade, lean production and increasingly efficient value-added chains, fast and timely delivery of goods is of high and ever-increasing importance. Fast and reliable logistics is an important component of every efficient company in all areas of the value-added process. Automated systems are increasingly helping to make the dispatch and delivery of goods and material provision processes faster and more reliable. Possible cable lengths of up to 100 meters when using the GigE interface are ideally suited for this application scenario. In addition, multi-camera systems can be used with high efficiency in large warehouses and to optimize various processes.



4.5 Retail

The retail sector requires reliable camera technology. Camera systems can be used in many different ways, such as in reverse vending machines or cash dispensers. The multi-camera setups also support the recording of customer numbers and behavior. Accordingly, cameras are used in the retail sector to track which customers (women or men) stop where longer, which posters they look at longer, which items they spend time with, and which goods they ignore and simply walk past.

Retailers use the data obtained to optimize the display of goods in the store and ultimately attract more buyers. In addition, there is a growing trend towards self-checkout systems, where customers pay at a vending machine without a cashier. The various cameras used handle customer recognition and payment. The GigE interface technology is an ideal match for the demand for a simple infrastructure of multi-camera systems and the long cables required in this application area.



5. Conclusion and Outlook

Gigabit Ethernet is the interface with the greatest technological flexibility in terms of cable length and multi-camera functionality. It will therefore continue to play an important role in many types of applications and will be the first choice for users when multi-camera systems are used. Accordingly, the interface cards used in these systems are of great importance for the overall application. When selecting and using GigE cameras and interface cards, it is important to rely on the GigE Vision standard and to comply with it to guarantee the appropriate quality of the systems. It is crucial to rely on tested and approved products to meet the high requirements of machine vision applications.

However, the ultimate „all things to everyone“ solution for industrial cameras does not exist. GigE, USB and CoaXPress will probably collectively dominate the future interface landscape. However, certain interface technologies are more suited for certain applications. Selection tools such as the *Interface Advisor* provide assistance in selecting the appropriate interface for the system. Another tool, the *Vision Solution Guide*, supports the selection of a suitable camera for the application, and compatible components such as PC cards

Tips for the Selection of Compatible PC Cards

- If the on-board host controller of the PC is already occupied by a peripheral, dedicated PC cards are recommended to avoid malfunctions.
- Use tested and approved drivers from the manufacturer.
- Dedicated chipsets on PC cards can save computational power.

Interface	Cable Length in m	Max. Bandwidth	Multi-Camera	Costs	„Real Time“	„Plug-and-Play“
USB3 VISION	8 m	350-400 Mbps	🟥	🟩	🟩	🟩
GiGE VISION	100 m	100 Mbps	🟩	🟩	🟧	🟧
CoaXPress	40 m	12,5 Gbps	🟥	🟥	🟩	🟧

Interface comparison at a glance

Author

Zuschant Chugh
Trainee Product Manager

Zuschant Chugh is responsible for the product categories including PC cards, peripherals and accessories. He holds a master's degree in Industrial Engineering and Management and prior to joining Basler, he spent three years in the IT and marketing department of a well-known German railroad logistics company.

Contact

Zuschant Chugh
Trainee Product Manager - Product Management
Toolbox + Accessories

Tel. +49 4102 463 404
Fax + 49 4102 463 46 404
Email: Zuschant.Chugh@baslerweb.com

Basler AG
An der Strusbek 60-62
22926 Ahrensburg
Germany

About Basler

Basler is a leading international manufacturer of high-quality imaging components for computer vision applications. In addition to classic area scan and line scan cameras, lenses, frame grabbers, light modules, and software, the company offers embedded vision modules and solutions, 3D products, as well as customized products and consulting services. Basler's products are used in a variety of markets and applications, including factory automation, medical, logistics, retail, and robotics. They are characterized by high reliability, an excellent price/performance ratio, and long-term availability. Founded in 1988, the Basler Group employs around 800 people at its headquarters in Ahrensburg and other locations in Europe, Asia and North America. Thanks to its worldwide sales and service organization and cooperation with renowned partners, it offers solutions that fit for customers from a wide range of sectors.

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Basler AG
Germany, Headquarters
Tel. +49 4102 463 500
Fax +49 4102 463 599
sales.europe@baslerweb.com
www.baslerweb.com

Basler, Inc.
USA
Tel. +1 610 280 0171
Fax +1 610 280 7608
sales.usa@baslerweb.com

Basler Asia Pte Ltd.
Singapore
Tel. +65 6367 1355
Fax +65 6367 1255
sales.asia@baslerweb.com

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