GUIDE TO UNDERSTANDING
MACHINE VISION STANDARDS

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GLOBAL COORDINATION OF MACHINE VISION STANDARDIZATION

A cooperation between A3 Vision & Imaging, CMVU, EMVA, JIIA and VDMA*

www.automate.org

european machine vision association

www.emva.org

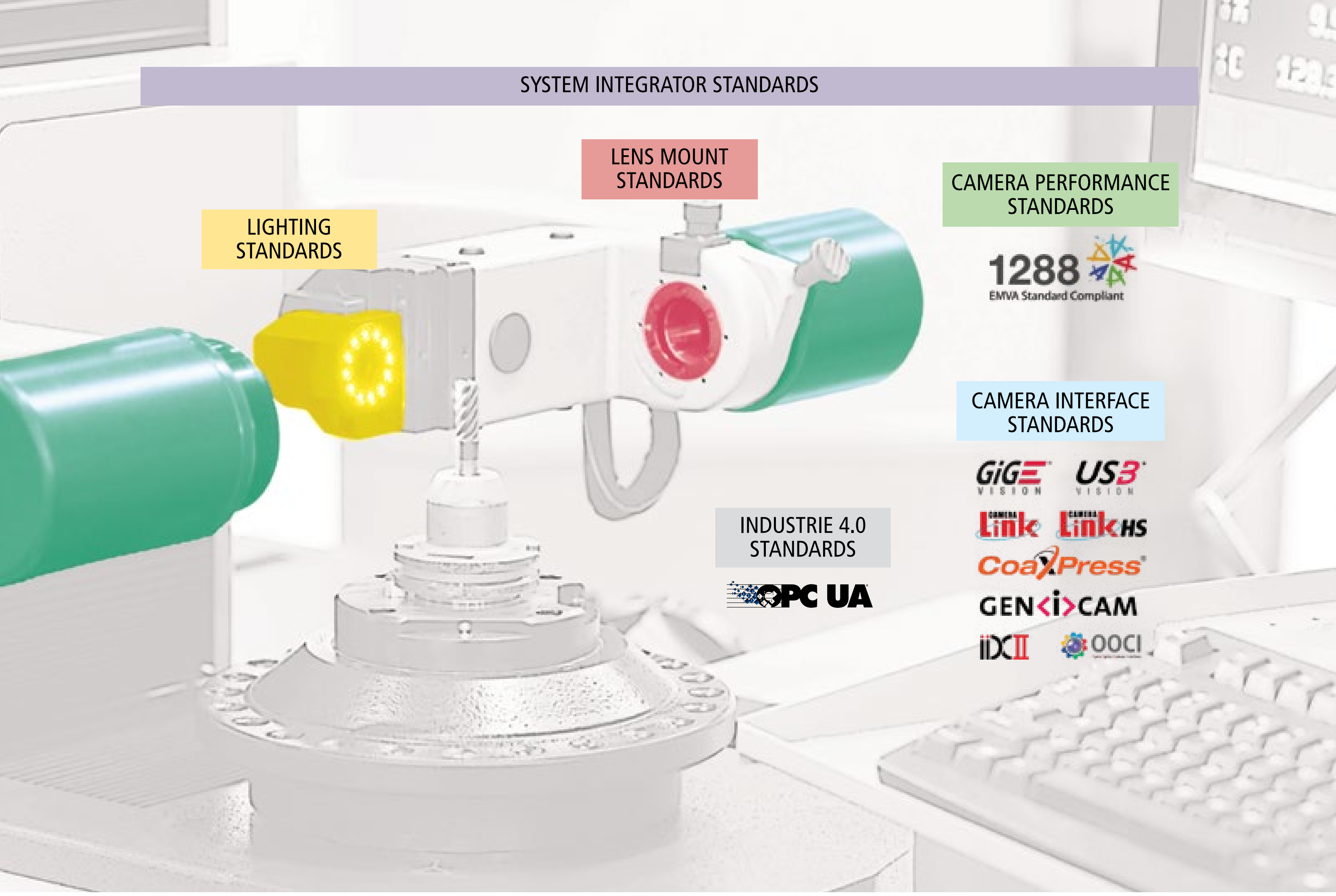
jiia.org

www.china-vision.org

www.vdma.org/vision

Member-supported trade associations promote the growth of the global vision and imaging industry. Standards development is key to the success of the industry and its trade groups help fund, maintain, manage and promote standards. In 2009, three leading vision associations, A3 Vision & Imaging, EMVA and JIIA began a cooperative initiative to coordinate the development of globally adopted vision standards. They were joined in 2014 by VDMA Machine Vision and in 2016 by CMVU. This publication is one product of this cooperative effort.

*G3 is an initiative of A3 Vision & Imaging, CMVU, EMVA, JIIA and VDMA and does not form a legal entity.



Standards for Each Element of the Vision System

This is a comprehensive look at the various global machine vision standards which make vision technology less expensive and easier to use. This brochure covers the various interface, performance, lens mount, lens control, lighting and system integrator standards. It is your one stop reference to all the currently recognized and promoted global vision standards.

Digital technology has revolutionized the ability to capture, analyze and use, both visible and non-visible light energy, at high speed. This has enabled ever expanding application of vision technology to automate manufacturing, to streamline and optimize processes, and to drive ever expanding research into our physical environment.

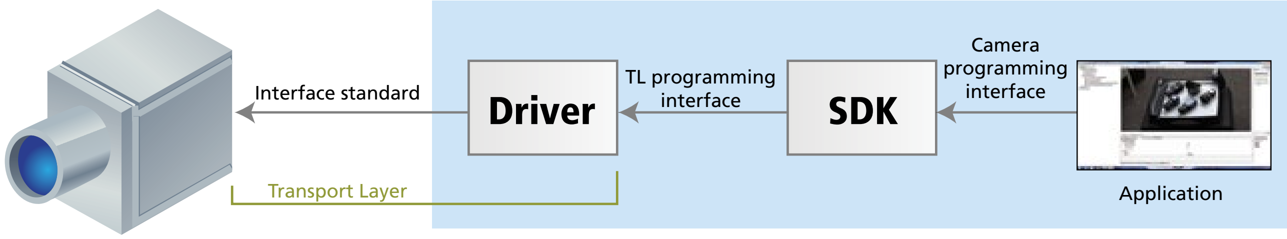
With the advent of this new technology in the late 1990s, it became apparent that there were great benefits to be derived from standardizing the more common elements of vision systems. This drove the development of camera interface standards that drove down costs, simplified system design/installation, and ensured component interoperability. The first example of this was the Camera Link standard in 2000, which led to others such as Camera Link HS, CoaXPress, GigE Vision and USB3 Vision. Additionally, various performance, lens, lens control and lighting standards have been developed to help proliferate vision technology. The goal of this brochure is to help communicate the vast opportunity that vision technology offers to make your current operations more efficient and to discover future, untapped applications.

CAMERA INTERFACE STANDARDS

A camera interface standard codifies how a camera is connected to a PC, providing a defined model that allows simpler, more effective use of vision technology. A vision system is comprised of various components including cameras, frame grabbers and vision libraries; often from multiple manufacturers. Interface standards ensure that compliant components interoperate seamlessly. The camera interface standards are divided into 2 groups: hardware and software.

Vision applications require four basic tasks: finding & connecting to the camera; configuring the camera; grabbing images from the camera; and dealing with asynchronous events signaled by or to the camera.

Key Functions provided by Camera Interface Standards



Two layers of software help with these tasks. The first layer is the transport layer (TL) which enumerates the camera, provides access to the camera's low-level registers, retrieves stream data from the device, and delivers events. The transport layer is governed by the hardware interface standard. Depending on the interface type, the transport layer requires a dedicated frame grabber (Camera Link, Camera Link HS, CoaXPress) or a bus adapter (FireWire, GigE Vision, USB3 Vision).

The second layer is the image acquisition library which is part of a software development kit (SDK). The SDK can be a stand-alone item, provided with a frame grabber, or in an image processing library. It uses the transport layer to access the camera functionality and allows grabbing images.

There are 5 principle hardware interface standards (Camera Link, Camera Link HS, CoaXPress, GigE Vision and USB3 Vision) and 2 principle software interface standards (GenICam and IIDC2).

Hardware interface standards ensure that cameras can be connected to any driver or frame grabber. The programming interface of software interface standards makes sure that the drivers/SDKs can be used from different vision libraries or even directly by developers. Developers can exchange cameras, drivers or even the whole interface technology without having to make significant changes to software if they use a standards-based SDK.

The Camera Link standard was initially released in 2000. It is a robust, well-established communications link that standardizes the connection between cameras and frame grabbers and defines a complete interface, including provisions for data transfer, camera timing, serial communications, and real-time signaling to the camera. Camera Link is a non packet-based protocol and remains the simplest camera/frame grabber interconnect standard. Currently in version 2.1, the standard specification includes Mini Camera Link connectors, Power over Camera Link (PoCL), PoCL-Lite (a minimized PoCL interface supporting base configurations) and cable performance specifications.

Speed

Camera Link was built for real-time, high speed communication. The high bandwidth of 255 Mbytes/s for one cable and up to 850 Mbytes/s for two cables assures fast transfer of images with no latency issues.

Receiver Device

Frame grabber.

Cable

Camera Link defines its own dedicated cable. Cameras and frame grabbers can be easily interchanged using the same cable. Maximum cable length is in the range of 4 to 15 meters depending on camera clock rate. Mini Camera Link provides a small footprint when space is an issue.

Connectors

MDR 26-pin connector; SDR, HDR 26-pin connector (Mini Camera Link); HDR 14-pin connector (PoCL-Lite).

Camera Power Supply

Using PoCL, a PoCL camera can be powered by a PoCL frame grabber through the Camera Link cable.

Other Differentiators

Camera Link has optional GenICam support for plug and play interoperability. Use of up to two cables per camera is possible.

Initial Release Date	**October 2000**		
Output configurations	**Configuration**	**Image data throughput**	**Number of cables**
	Lite	100 Mbytes/s	1
	Base	255 Mbytes/s	1
	Medium	510 Mbytes/s	2
	Full	680 Mbytes/s	2
	80-bit	850 Mbytes/s	2
Camera control	**Uplink channel**	Asynchronous serial comms	
	Downlink channel	Asynchronous serial comms	
	Trigger input signal	4 direct signal from frame grabber to camera	
Receiver devices	Frame grabber		
Supported transfer topologies	Point-to-point		
Cabling	**Types**	**Max. length** *(typical at 85 MHz)*	**Power over cable** *(wattage at camera)*
	Lite	10m	4W
	Base	10m	4W (optional)
	Medium	10m	8W (optional)
	Full	5m	8W (optional)
	80-bit	4m	8W (optional)

HDR 14-pin connector (PoCL-Lite)

SDR, HDR 26-pin connector (Mini Camera Link)

MDR 26-pin connector

More Info at
https://qrco.de/bcOs2P

The Camera Link HS standard was released in May 2012, improving on Camera Link by using off-the-shelf cables to extend reach and also increasing the bandwith using a single, low-cost fibre cable. Camera Link HS features include: single bit error immune protocols; 16 bidirectional General Purpose Input Output (GPIO) signals; system level functions such as synchronizing multiple parallel processing frame grabber; and frame by frame control of camera operating mode from the host. Camera Link HS is supported at 3.125 and 5.0 Gbits/s per lane with the M protocol and at 10.3, 12.5, 13.8, 15.9 Gbits/s per lane with the X protocol. Unencrypted VHSIC Hardware Description Language (VHDL) IP cores are available, reducing interconnection issues and development risks when integrating Camera Link HS into original equipment manufacturer (OEM) or custom implementations. Even though Camera Link HS is a packet based protocol, it achieves trigger jitter of ±3.2 nanoseconds (ns) using the IP core with typical latencies of 150 ns and GPIO latency and jitters in the 300 ns range. Data forwarding is achieved with low cost copper cabling to neighboring PCs.

Speed

Camera Link HS is designed for parallel processing and supports 1 through 8 cables with per-cable effective bandwidths of 1200/1850 Mbytes/s (F2 fiber), 2100/3300 Mbytes/s
(C2 copper), or 8400 Mbytes/s (C3 copper/fiber)

Receiver Device

Frame grabber.

Cable

C2/C3 copper–15m/2m; Plug–on Active Optical Cable (AOC)-100m; F2 (SFP+) copper/fiber optic cable–5m/300m

Connectors

Copper cable: SFF-8470 (InfiniBand or CX4); Fiber optic cable: Plug on active optical or SFP+ connector/LC optical.

Camera Power Supply

Separate connector

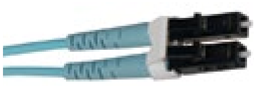
Other Differentiators

Direct connection to FPGA serdes is possible.

SFP+ connector

SFF-8470 connector (InfiniBand, CX4 or active optical cable)

Fiber optic cable



Initial Release Date	**May 2012**		
Output configurations	**Configuration**	**Image data throughput**	**Number of cables**
	C2 - (CX4 cables)	2100/3300 Mbytes/s	1
	C3 - (CX4 cables)	8400 Mbytes/s	1
	F2- (SFP+ connector)	1200/1850 Mbytes/s	1
Camera control	Uplink channel	Dedicated 300 (C2) or 1200 (F2,C3) Mbytes/s	
	Downlink channel	Shared with image data	
	Trigger input signal	Camera input pins, from frame grabber with optional frame by frame camera mode control	
Receiver devices	Frame grabber		
Supported transfer topologies	Point-to-point and/or data splitting/data forwarding possible		
Cabling	**Types**	**Max. length**	**Power over cable** *(wattage at camera)*
	C2/C3 (Copper)	15m/2m	No power
	C2/C3 Active Optical Cable (Plug On)	100m	No power
	F2 Multi-mode fiber	300m	No power
	F2 Single-mode fiber	5000+ m	No power

More Info at
https://qrco.de/bcOs53

The CoaXPress (CXP) standard was released in December 2010. It provides a high speed interface between cameras and frame grabbers and allows long cable lengths. In its simplest form, CoaXPress uses a single coaxial cable to: transmit data from a camera to a frame grabber at up to 12.5 Gbits/s; simultaneously transmit control data and triggers from the frame grabber to the camera at up to 41.7 Mbits/s; and provide up to 13W of power to the camera. Link aggregation is used when higher speeds are needed, with more than one coaxial cable sharing the data. Version 2.1 adds support for GenICam GenDC and a separate "CoaXPress over Fiber" document defines how to run the CoaXPress protocol over fiber optic cables.

Speed

CoaXPress supports real-time triggers, including triggering very high speed line scan cameras. With a 41.7 Mbits/s uplink to the camera, trigger latency is 1.7 microseconds (μs), or with the optional high speed uplink, it is typically 150 ns. CoaXPress already supports the fastest cameras on the market with significant headroom by allowing up to 7.2 Gbytes/s with 6 links in one cable.

Receiver Device

Frame grabber.

Cable

At 1.25 Gbits/s link speed (CXP-1), CoaXPress supports cable lengths of over 100m; at 3.125 Gbits/s (CXP-3), the maximum length is 85m; and even at the maximum 12.5 Gbits/s (CXP-6), 25m cables with 7mm diameter can be used. Longer lengths are possible with larger diameter cables.

Connectors

The small micro-BNC and the widely used BNC connectors can be used at all speeds up to 12.5 Gbits/s. The small DIN 1.0/2.3 can be used up to 6.25 Gbit/s and can also be combined into a multiway connector.

Camera Power Supply

Through CoaXPress cable.

Other Differentiators

Support for GenICam including GenApi, SFNC and GenTL (including image streaming) is mandatory. GenICam GenDC and IIDC2 support is optional.

Initial Release Date	**December 2010**		
Example output configurations	**Configuration**	**Image data throughput**	**Number of cables**
	CXP-3	300 Mbytes/s	1 coax
	CXP-12	1200 Mbytes/s	1 coax
	4x CXP-6	2400 Mbytes/s	4 coax, can be in 1 cable
	6x CXP-12	7200 Mbytes/s	6 coax, can be in 1 cable
	4x CXP-12 over fiber	4800 Mbytes/s	1 QFSP+
Camera control	**Uplink channel**	Dedicated; 20.8 or 41.7 Mbits/s link is standard; optional up to 12.5 Gbits/s with additional coax	
	Downlink channel	Shared with image data	
	Trigger input signal	Protocol supports trigger from frame grabber; camera can also have trigger inputs	
Receiver devices	Frame grabber		
Supported transfer topologies	Point-to-point	Camera can share data across multiple frame grabbers	
Cabling	**Types**	**Max. length**	**Power over cable** *(wattage at camera)*
	CXP-3	85m	13W
	CXP-12	25m	13W
	4x CXP-6	35m	52W
	6x CXP-12	25m	78W
	4x CXP-12 over fiber	10km	N/A

Micro-BNC Connector

Multiway DIN connector

BNC connector

DIN 1.0/2.3 connector

More Info at
https://bit.ly/2CSm9Mz

The GigE Vision standard is a widely adopted camera interface standard developed using the Ethernet (IEEE 802.3) communication standard. Released in May 2006, the standard was revised in 2010 (version 1.2), 2011 (version 2.0) and 2018 (version 2.1). GigE Vision supports multiple stream channels and allows for fast error-free image transfer over very long distances using standard Ethernet cables. Hardware and software from different vendors can interoperate seamlessly over Ethernet connections at various data rates. Other Ethernet standards, such as IEEE 1588, are leveraged to provide deterministic triggering.

Speed

Currently 1, 2.5, 5 and 10 Gbits/s systems are readily available.

Receiver Device

PC (direct), with GigE interfaces built into almost all PCs and embedded systems, no additional interface card (frame grabber) is necessary in many situations.

Cable

Depending on the cable and number of cameras, GigE Vision allows cable lengths up to 100m (copper) and 5,000m (fiber optic) using a single camera.

Connectors

Connectors available for GigE Vision: Copper Ethernet; Copper Ethernet with vision locking screws; Copper Ethernet with latch-lock; Copper Ethernet with environmental seal; 10 Gigabit Ethernet direct attach cable; Ethernet fiber optic cable.

Camera Power Supply

Through Ethernet cable (POE) or externally

Other Differentiators

As each GigE camera has its own IP-address, there is no limit to how many cameras can be operated on the same network.

Copper Ethernet cable

Copper Ethernet with vision locking screws

IX Connector, Copper Ethernet with latch-lock

M12 Connector, Copper Ethernet with environmental seal

10 Gigabit Ethernet direct attach cable

Ethernet fiber optic cable

More Info at
https://qrco.de/bcOsGT

Initial Release Date	**May 2006**		
Output configurations	**Configuration**	**Image data throughput**	**Number of cables**
	1 GigE	115 Mbytes/s	1 cable
	2.5 GigE	280 Mbytes/s	1 cable
	5 GigE	570 Mbytes/s	1 cable
	10 GigE	1100 Mbytes/s	1 cable
	WiFi	25 Mbytes/s	N/A
Camera control	**Uplink channel**	Symmetric with downlink channel	
	Downlink channel	Shared with image data	
	Trigger input signal	Hardware trigger on camera. Software trigger, optionally synchronized by Precision Time Protocol (IEEE1588)	
Receiver devices	Network interface card (NIC) can be on motherboard or inserted as an add-in card. Possibility to use a GigE Vision frame grabber.		
Supported transfer topologies	Point-to-point, multiple destinations	Direct connection to network card or to an Ethernet switch is possible. Support for multicast and broadcast.	
Cabling	**Types**	**Max. length** *(typical at 85 MHz)*	**Power over cable** *(wattage at camera)*
	CAT-5e/CAT-6a/CAT-7	100m	Optional 13W (IEEE802.3af) Optional 25W (IEEE802.3at)
	Multi-mode fiber	500m	No power
	Single-mode fiber	5000m	No power
	SFP+ direct attach	10m	No power

USB3 VISION

The USB3 Vision standard was initiated in late 2011, with version 1.0 published in January 2013. While the standard is new, the machine vision industry is not unfamiliar with USB technology. The USB interface brings broad levels of consumer awareness, easy plug and play installation, and high levels of performance. The expertise of many companies was combined to create a standard that accommodates the varied needs within the machine vision industry. This approach allows off-the-shelf USB host hardware and nearly any operating system to take advantage of hardware direct memory access (DMA) capabilities to directly transfer images from the camera into user buffers. Leveraging camera control concepts from the GenICam standard means end users can easily implement USB3 Vision into existing systems. With the USB-IF organization's established track record of continuously updating the USB standard to improve speed and add features (USB 3.2 allows up to 20Gbit/s transfers), USB3 Vision will continue to leverage these improvements.

Speed

The standard builds upon the inherent aspects of USB 3.0, bringing end-to-end data reliability at over 400 Mbytes/s. This transfer speed is further improved with 10Gbit/s and 20Gbit/s speeds standardized in USB 3.1 and 3.2.

Receiver Device

PC (direct). With USB interfaces built into almost all PCs and embedded systems, no additional interface card (frame grabber) is necessary in many situations.

Cable

Standard passive copper cable 3-5m; active copper cable 8+m; multi-mode fiber optic cable 100m.

Connectors

USB3 Vision type connectors: host side (standard A locking) and device side (micro-B locking). Locking Type-C connectors also defined by USB standard and optionally used by hosts and devices.

Camera Power Supply

Through standard passive copper cable 4.5W (5V, 950 mA) maximum; power supply through active cable solutions varies.

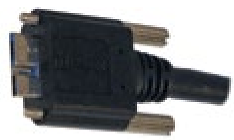
Other Differentiators

Frame grabber like image transfer performance.

Initial Release Date	**January 2013**		
Output configurations	**Configuration**	**Image data throughput**	**Number of cables**
	SuperSpeed	400 Mbytes/s	1 cable
	SuperSpeedPlus Gen2x1	Up to 10Gbit/s	1 cable
	SuperSpeedPlus Gen2x2	Up to 20Gbit/s	1 cable
Camera control	**Uplink channel**	Symmetric with downlink channel	
	Downlink channel	Shared with image data	
	Trigger input signal	Hardware trigger on camera. Software trigger	
Receiver devices	Built-in interfaces, add-in cards		
Supported transfer topologies	Device to host	Star topology with switched data supported via hub. 127 devices maximum are connectable on one USB bus.	
Cabling	**Types**	**Max. length**	**Power over cable** *(wattage at camera)*
	Standard Passive Copper	3-5m	4.5W/100W (Type-C)
	Active Copper	8+m	Varies
	Multimode Fiber Optic	100m (typ)	No power

Host side (standard A locking)

Device side (micro-B locking)



Type-C Locking (vertical)

Type-C Locking (horizontal)

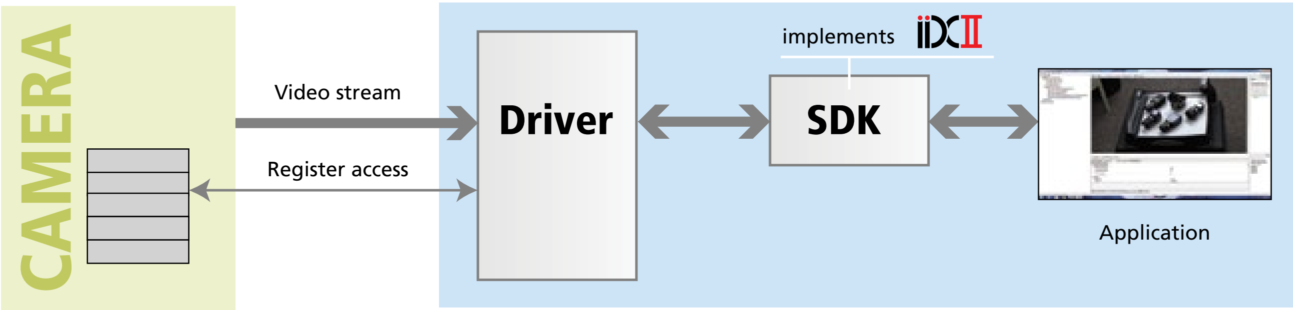
More Info at
https://qrco.de/bcOsJy

HARDWARE INTERFACE STANDARD COMPARISON

Name of Standard	IEEE1394 + IIDC		Camera Link			Camera Link HS		
Topology	Daisy chain		Point-to-point			Point-to-point, data splitting		
Transmission format	Packet-based		Parallel			Packet-based		
Image transmission robustness	Error detection only		None			Data retransmission/ Forward error correction		
Related software standard	Mandatory: IIDC		Optional: GenICam, CLProtocol, GenCP			Mandatory: GenICam GenApi, GenCP, SFNC Optional: GenICam GenTL		
Certification requirements	Self certification		Registration form, self certification			Registration form, compliance matrix		
Configuration	IEEE1394a (S400) IEEE1394b (S800)	IEEE1394b (S1600)	BASE	MEDIUM/ FULL	80-bit	C2	C3	F2
Bandwidth (image data)	★ ≤ 100 Mbytes/s	★★ ≤ 200 Mbytes/s	★★★ ≤ 500 Mbytes/s	★★★★ ≤ 1000 Mbytes/s	★★★★ ≤ 1000 Mbytes/s	★★★★★ ≤ 5000 Mbytes/s	★★★★★★ > 5000 Mbytes/s	★★★★★ ≤ 5000 Mbytes/s
Control channel	Full-duplex, shared with image data		Dedicated serial port			Dedicated uplink, shared downlink		
Cable types	IEEE 1394		Camera Link			CX4	CX4	Fiber
Cable length (passive cable)	★ ≤ 10 meters		★ ≤ 10 meters			★★ ≤ 20 meters ★★★★ AOC ≤ 120 meters	★ ≤ 10 meters ★★★★ AOC ≤ 120 meters	★★★★ ≤ 120 meters
Power over the cable	Mandatory		Optional			None		
Wattage available at camera	45W max (depends on PC)		4W	8W	8W	N/A		
Frame grabber required	No		Yes			Yes		
Camera trigger input signal	Direct on camera		On camera or from frame grabber			On camera or from frame grabber		
Trigger latency - frame grabber to camera (link latency, protocol overhead only)	N/A		★★★★★ < 100 ns			★★★★ ≥ 100 ns		

CoaXPress				GigE Vision				USB3 Vision		
Point-to-point				Point-to-point, network				Point-to-point, tiered-star		
Packet-based				Packet-based				Packet-based		
Error detection only				Data retransmission				Data retransmission		
Mandatory: GenICam GenApi, GenTL, SFNC				Mandatory: GenICam GenApi, SFNC				Mandatory: GenICam GenApi, GenCP, SFNC		
Optional: GenICam GenDC, IIDC2				Optional: GenICam GenTL				Optional: GenICam GenTL, IIDC2		
Registration form, electrical/protocol/interoperability compliance tests, PlugFest				Registration form, compliance matrix, device validation software, PlugFest				Registration form, compliance matrix, device validation software, electrical compliance tests, PlugFest		
CXP-12	4x CXP-6	6X CXP-12	4X CXP-12 over Fiber	1 GigE	2.5 GigE	5 GigE	10 GigE	SuperSpeed 5 Gbits/s	SuperSpeed+ Gen 2x1	SuperSpeed+ Gen 2x2
★★★★★ ≤ 5000 Mbytes/s	★★★★★ ≤ 5000 Mbytes/s	★★★★★★ > 5000 Mbytes/s	★★★★★ ≤ 5000 Mbytes/s	★★ ≤ 125 Mbytes/s	★★★ ≤ 300 Mbytes/s	★★★ ≤ 600 Mbytes/s	★★★★ ≤ 1000 Mbytes/s	★★★ ≤ 500 Mbytes/s	★★★★ ≤ 1000 Mbytes/s	★★★★ ≤ 2000 Mbytes/s
Dedicated uplink, shared downlink				Full-duplex, shared with image data				Full-duplex, shared with image data		
Coaxial			Fiber	CAT-5e/6a/7, Fiber			CAT-6a/7, Fiber	SuperSpeed USB (Copper)	SuperSpeed USB (Fiber Adapter)	
★★★ ≤ 50 meters	★★★ ≤ 50 meters	★★★ ≤ 50 meters	★★★★★ > 120 meters	★★★★ ≤ 120 meters			★★★★★ > 120 meters	★ ≤ 10 meters	★★★★ ≤ 120 meters	
Mandatory			None	Optional				Mandatory		
13W	52W	78W	N/A	13W (IEEE802.3af) 25W (IEEE802.3at)				4.5W/100W (Type-C)		
Yes				No				No		
On camera or from frame grabber				Direct on camera				Direct on camera		
★★★★ ≥ 100 ns				N/A				N/A		

The IIDC2 standard, which is a successor to IIDC for FireWire cameras, defines a flexible-fixed camera control register layout. All details are defined for how each feature, such as exposure time, is mapped to the register space, representing a very simple approach to camera control.



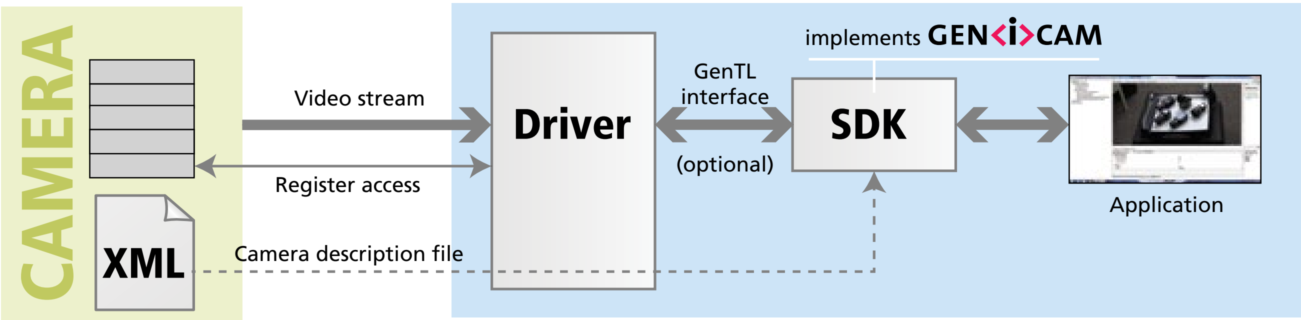
IIDC2 aims to be:

- Easy to implement and use
- Accessible to camera control registers
- Expandable for vendor specific functions
- A common controlling method for all cameras
- Usable on IEEE1394, USB3 Vision, CoaXPress and future interfaces
- Able to be mapped to a GenICam interface

The standard offers an easy method for controlling cameras by only reading/writing to registers directly inside the camera. All information regarding camera functionality is in the camera control registers. Users can determine supported features by reading the registers. The register mapping works as a semi-fixed method, meaning a fixed mapping of accessibility and a free mapping for expandability. The camera functions are categorized into basic functions (fixed register layout and its behavior) and expanded functions. Functions can be added freely by the vendor, its register layout is selectable from the list in the specification and its behavior is vendor-specific. When using IIDC2 registers with GenICam, the camera description file can be common for all cameras because the IIDC2 register layout is defined in the specification.

More Info at
https://bit.ly/2COrIM5

GenICam (Generic Interface for Cameras) provides a generic programming interface for all kinds of devices (mainly cameras), no matter what interface technology they are using or what features they are implementing. The result is that the application programming interface (API) will be identical regardless of interface technology.



The GenICam standard is made up of a range of modules:

- **SFNC (Standard Feature Naming Convention):** This is the part of GenICam that most users see. It standardizes the name, type, meaning and use of device features so that devices from different vendors always use the same names for the same functionality. These features are typically shown in a tree view, or can be directly controlled by an application. One related standard is the PFNC (Pixel Format Naming Convention) which defines how to consistently name pixel formats and lists the formats in use. Another extension to SFNC is OOCI (Open Optics Camera Interface) which provides standard interface for optical components inside of, or attached to, cameras, no matter what wire interface technology the cameras are built on. The optical components covered by OOCI are Lenses, Filters, Filter Wheels, Shutters, Apertures, etc.
- **GenApi (Application Programming Interface):** This defines the mechanism used to provide the generic API via self-describing XML file in the device. It is also the name of the reference implementation of GenICam, provided as production-quality code, as part of the GenICam download. Part of GenApi is the Schema which defines the format of the XML file.
- **GenTL (Transport Layer):** This standardizes the transport layer programming interface, which comes with a GenTL Producer Framework reference implementation for an easy start with GenTL. It is a low-level API to provide a standard interface to a device regardless of the transport layer (with or without a frame grabber). It allows enumerating devices, accessing device registers, streaming data and delivering asynchronous events. GenTL also has its own SFNC.
- **GenCP (Control Protocol):** This is a low-level standard to define the packet format for device control and is used by interface standards to save them needing to reinvent a control protocol for each new standard.
- **GenDC (Data Container):** This is a low-level standard to define the data packet format to allow devices to send any form of data to a host system. It avoids the need for each interface standard to duplicate work on adding new data formats.

Members of the GenICam standard group maintain a reference implementation that parses the file containing the self-description of the camera. The production quality code is available in C++, Java and Python, and can be used free of charge. It is highly portable and available on a range of operating systems and compilers.

Most available SDK implementations use this reference implementation as the engine under the hood, thus ensuring a high degree of interoperability.

More Info at
https://bit.ly/2pU3GGR

	GenICam	IIDC2
Basics		
Initial release date	September 2006	January 2012
Current version	**https://bit.ly/39lQwcl**	**https://bit.ly/2COrIM5**
Hosting association	EMVA	JIIA
Standard website	www.genicam.org	jiia.org
Transport Layer Programming Interface	supported (GenTL module)	not supported
Enumerating cameras	yes	-
Accessing camera registers	yes	-
Streaming video data, including GenDC and 3D data	yes	-
Delivering asynchronous events	yes	-
Supported by hardware standards		
mandatory	CXP	-
optional	1394, CL, CLHS, GEV, U3V	-
Camera Programming Interface	supported (GenApi + SFNC module)	supported
Method of operation	camera description file	hard-coded register set
Number of defined standard features incl. PFNC and OOCI	500+	72
Custom feature support	yes	yes
Event delivery	yes	yes
Chunk and GenDC data access	yes	-
Supported by hardware standards		
mandatory	CXP, CLHS, GEV, U3V	-
optional	1394, CL	1394, CXP, U3V
Reference Implementation	available (GenApi module)	not required
Free of charge	yes	-
Production quality	yes	-
Programming language	C++, incl. Java/Python bindings	-
Supported operating systems	Windows (32/64), Linux (32/64/ARM), macOS	-
Supported compilers	Visual Studio, GCC	-

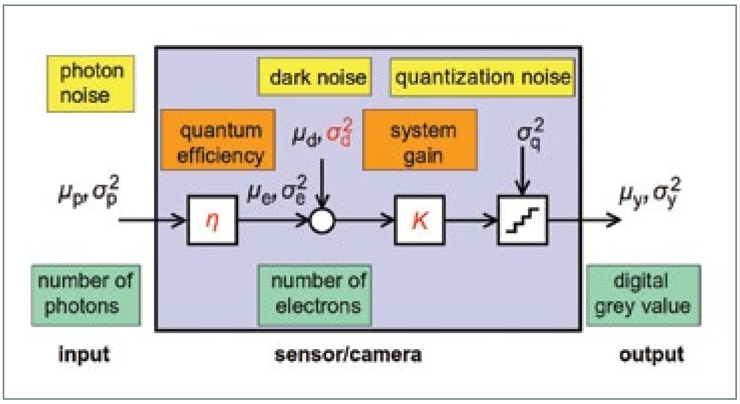
EMVA 1288 is the Standard for Measurement and Presentation of Specifications for Machine Vision Sensors and Cameras. Customers and users of vision components benefit from the standard's use as well as the component manufacturers.

Choosing the suitable camera for a given machine vision application often proves to be a challenging task. The data sheets provided by the manufacturers are difficult to compare. Frequently, vital pieces of information are not available and the user is forced to conduct a costly comparative test which still may fail to deliver all relevant camera parameters. This is where the EMVA 1288 Standard comes in. It creates transparency by defining reliable and exact measurement procedures as well as data presentation guidelines and makes the comparison of cameras and image sensors much easier.

The Standard is elaborated by a consortium of the industry leading sensor and camera manufacturers, distributors and component customers. Work on the 1288 standard started in 2004. Version 1 for monochrome cameras was released in August 2005. Release 3.1 came into effect on December 30, 2016, contains some refinements and introduced a design of a standardized summary datasheet for easy camera comparison. Since June 21, 2021, Release 4.0 is in effect, replacing Release 3.1.

Linear and General Camera Models

The 1288 standard has been extended to non-linear cameras and cameras with preprocessing. With some improvements the previous release is being continued in "Release 4.0 Linear". A new module "Release 4.0 General" has been added. For the linear model, all noise sources except for photon noise and quantization noise can be included into a single parameter, the variance of the dark noise. Thus, the model contains only three basic unknowns: the quantum efficiency, the dark noise, and the system gain. The general model is a true black box and contains no internal camera parameters. Still, it is possible to determine all 1288 performance parameters with the same measurements as with the linear model.



Standardized Summary Datasheet

The Standardized Summary Datasheet is still organized in the same way. It contains three major elements.

1. Operating point

Contains a complete description of the settings of the operating point at which the EMVA 1288 measurements have been acquired. Settings not specified are assumed to be in the factory default mode. This ensures that the measurements can be repeated anytime under the same conditions.

2. Photon Transfer Curve or Characteristic Curve and SNR Curve

For the linear model, the photon transfer curve shows best whether the camera is sufficiently linear. For the general model, the characteristic curve shows the type of non-linearity. The double-logarithmic SNR curve is a nice overall graphical representation of the camera performance parameters except for the dark current.

3. EMVA 1288 Performance Parameters

This column lists all EMVA 1288 performance parameters.

EMVA 1288 Compliance

If EMVA standard 1288 compliant data is published or provided to a customer or any third party, then the full datasheet must be provided. An EMVA 1288 compliant data sheet must contain all mandatory measurements and graphs as specified in the standard document for release 4.0 on https://www.emva.org/standards-technology/emva-1288/

Future Work

Adapted to the fast development of modern image sensors:

- Extended wavelengths range further into UV and SWIR
- Extension to all kind of image modalities
- Decomposition of nonuniformities into column, row, and pixel variations
- Measurement of cameras with lenses
- Better linearity measure

More Info at
https://bit.ly/2yi8jPx

Image sensors come in many different sizes in machine vision cameras. For example, 16mm or less diagonal, 35 mm format, 12k pixel line sensor, etc. In addition, with many different lens mount sizes, there can be confusion about which sensors sizes are appropriate for which lens sizes. The purpose of these standards is to provide guidance on proper combinations of lens and sensor sizes for optimal vision system design.

1. Lens Mount Standard Comparison

For purpose of comparison, Lens Mount Standards for Machine Vision are shown the following table.

	JIIA Standards					for Reference	
Name of Lens Mount Standard	S	NF	NF-J	TFL	TFL-II	CS	C
Hosting Association	JIIA	JIIA	JIIA	JIIA	JIIA	JEITA	JEITA
Standard Number	LE-005	LE-003	LE-006	LE-004	LE-004	TT-4506	TT4506
Initial Release Date	August 2012	December 2008	January 2016	July 2011	July 2011	July 1998	July 1998
Current Version	2018	2019	2016	2017	2017	B	B
Date of Latest Release	February 2018	October 2019	January 2016	March 2017	March 2017	January 2014	January 2014
Image Size Class	II	II	II	III	III	II	II
Image Size (mm)	4-16	4-16	4-16	16-31.5	16-31.5	4-16	4-16
Fixing Screws（Size × Pitch)	M12 x 0.5	M17 x 0.75	M17 x 0.75	M35 x 0.75	M48 x 0.75	1-32UN	1-32UN
Basic Major Diameter (mm)	12	17	17	35	48	25.4	25.4
Length from the Flange Surface to the Screw Edge (mm)	-	under 4.1	under 4.1	under 4.1	under 5.1	under 4.06	under 4.06
Flange Focal Distance (mm)	-	12	12	Camera: 17.526 Lens: 23.000 (using adapter)	17.5	12.500	17.526
Diameter of Flange Surface (mm)	-	under 20.0	under 20.0	under 40.0	under 60.0	under 30.15	under 30.15
Fit Diameter (mm), Tolerance Class	-	-	φ15.5 H6/f6	-	φ50 H7/g6	-	-

2. Recommended Mechanical Interfaces Applied for Each Image Size Classification

Cameras for machine vision applications use various Mechanical Interfaces depending on the used image sensor size. The Lens Working Group of the JIIA Standardization Committee had been working on the standardization of the Mechanical Interfaces applied to each image size classification so that end users can easily pair optimal combinations. These guidelines (JIIA LER-004) describe the recommended mechanical interfaces applied to "Each Image Size Classification" specified in JIIA LE-001.

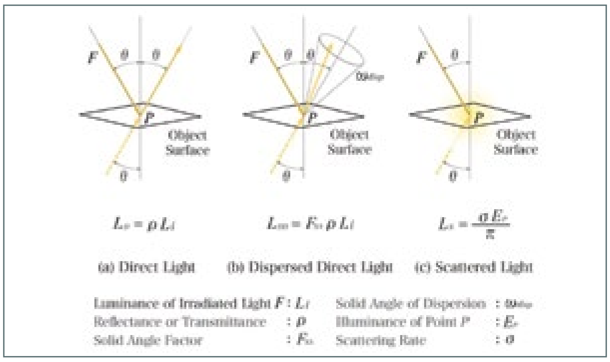
Image Size Class	Minimum Image Size [mm]	Maximum Image Size [mm]	Maximum Image Format [TYPE]	Mount Size [mm]	Recommended Mechanical Interface	
					1st choice	2nd choice
I	0	4	≈ 1/4	6.3	-	M6.3x0.5
				8	-	M8x0.3
II	4	8	≈ 1/2	10.5	-	M10.5x0.5
				12	S	-
				15.5	-	M15.5
				17	NF, NF-J	-
	8	16	≈ 1	25.4	C, CS	-
III	16	31.5	≈ 2	35	-	TFL
				42	M42x1	-
				48	48 mm Ring	-
					TFL-II	-
					F	-
IV	31.5	50	≈ 3	52	-	M52
				56	M58x0.75	-
V	50	63	≈ 4	64	-	-
				72	M72x0.75	-
VI	63	80	≈ 5	80	-	-
				90	M95x1	-
VII	80	100	≈ 6	100	M105x1	
				125	-	-

More Info at
https://bit.ly/2COrIM5

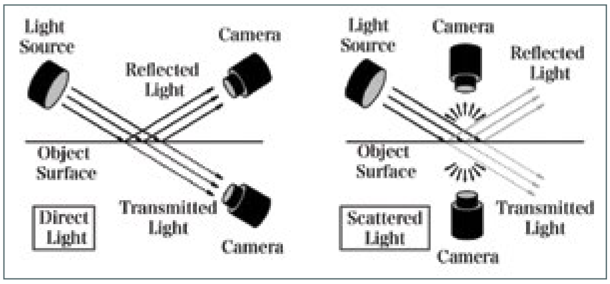
Lighting fulfills a critical role in image processing systems by ensuring that the targeted object provides sufficient contrast on the image sensor.

1. LI-001-2018
Lighting for Machine Vision/Image Processing System
Fundamentals of Design and Specifications on Brightness of Optical Irradiation

This standard specifies the basic items in the design of the illumination system and the brightness of the irradiation light.



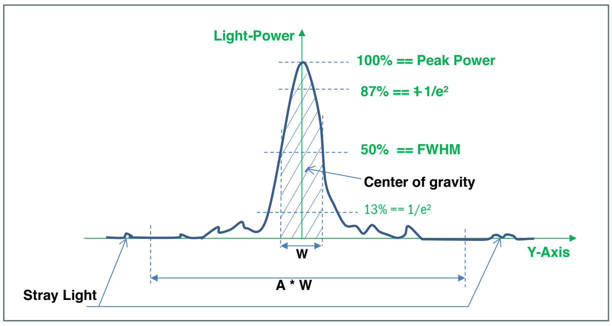
The classification of object light and its luminance



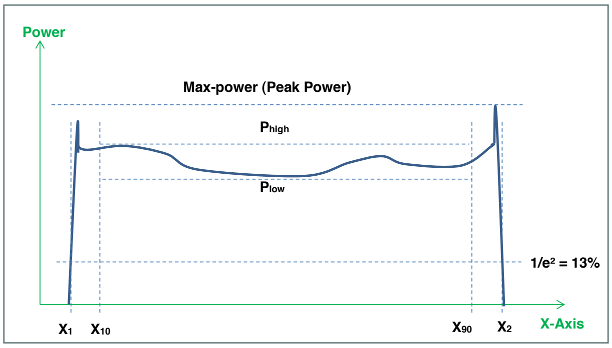
Bright field lighting and dark field lighting

2. LIR-001-2017
Laser Line Metrics for use in Machine Vision and Metrology Applications

These guidelines provide a consistent framework for measuring and reporting vision laser performance metrics.



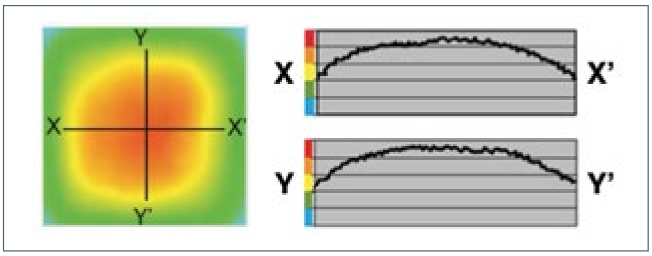
Cross section of the line (Gauss-fitted to remove effects from sensor resolution and noise)



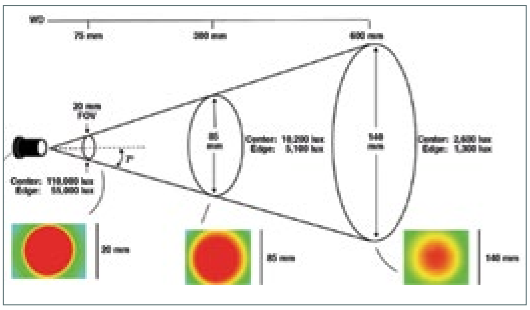
Power Distribution

3. LIR-002-2017
Light Performance Specification Guidelines

These guidelines provide a consistent framework for reporting vision lighting performance metrics and other secondary specifications.

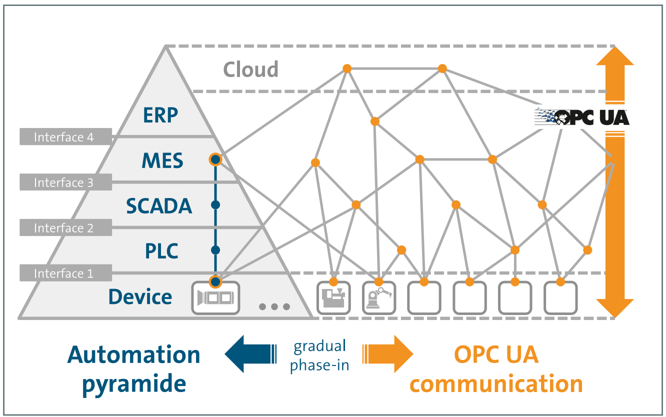


Light Pattern Uniformity, FOV/Shape


Projected light beam spread from source (where applicable)

More Info at
https://qrco.de/bcOsM7

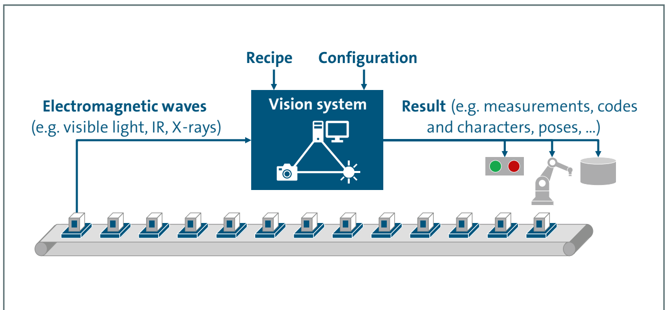
The OPC UA for Machine Vision Companion Specification (in short OPC Machine Vision) provides a generic information model for all vision systems - from simple vision sensors to complex inspection systems. Put simply, it defines the essence of any vision system that does not necessarily have to be a "machine" vision system. OPC Machine Vision is the accepted and officially supported OPC UA Companion Specification for vision systems by the OPC Foundation.



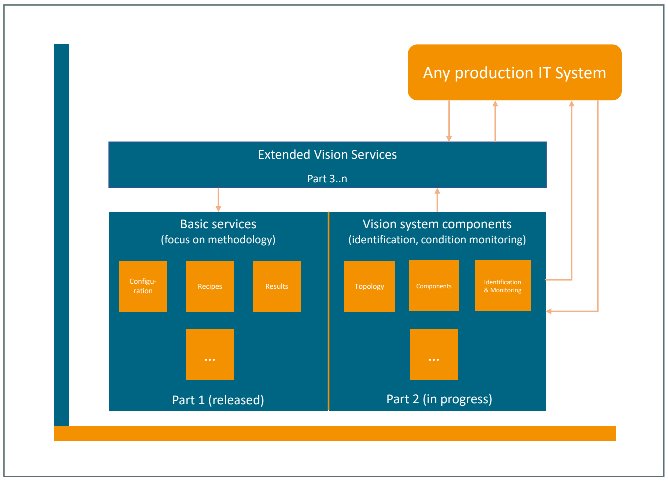
The scope is not only to complement or substitute existing interfaces between a vision system and its process environment by using OPC UA, but rather to create non-existing horizontal and vertical integration abilities to communicate relevant data to other authorized process participants, e.g. right up to the IT enterprise level. It is possible to have a gradual phase-in of OPC Machine Vision with coexisting other interfaces. The benefits are a shorter time to market by a simplified integration, a generic applicability and scalability and an improved customer perception due to defined and consistent semantics. Specific example: OPC Machine Vision enables Machine Vision to speak to the whole factory and beyond.

Fundamentals

A vision system is any system that has the capability to record and process digital images or video streams, typically with the aim of extracting information from this data. The output of a vision system can be any image-based information like measurements, inspection results, process control data, robot guidance data, etc.

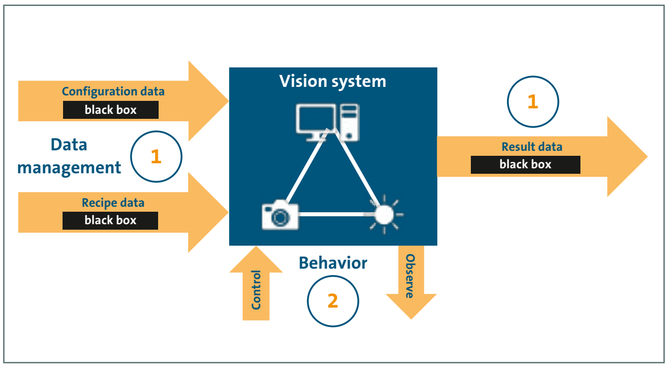


The basic concept of OPC Machine Vision is a subdivision into several parts. Part 1 includes the basis specification and describes an infrastructure layer which provides basic services in a generic way. Part 2 addresses the asset management and condition monitoring use cases of a vision system.



OPC Machine Vision, part 1

Part 1 describes an abstraction of the generic vision system, i.e. the representation of the so called "digital twin" of the system. It handles the management of recipes, configurations and results in a standardized way, whereas the contents stay vendor-specific and are treated as black boxes (1). It allows the control of a vision system in a generalized way, abstracting the necessary behavior via a state machine concept (2).



Part 2 and future parts

Part 2 of the OPC Machine Vision specification describes the composition of a machine vision system into its corresponding components. It addresses the identification and condition monitoring aspects of the components as well as the machine vision system itself. Future parts could provide extended OPC UA based services to communicate with the machine vision system.

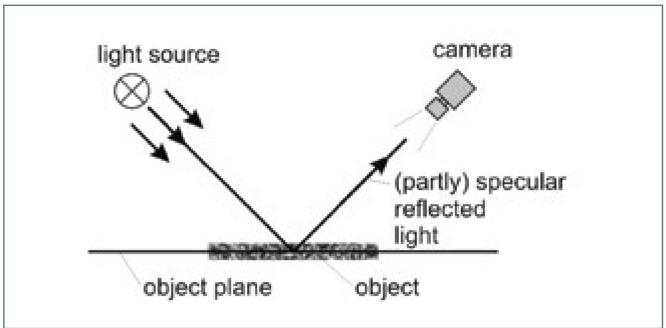
More Info at
https://qrco.de/bcP64B

The VDI/VDE/VDMA 2632 series of standards structures the communication between supplier and user. The standards help to avoid misunderstandings and to handle projects efficiently and successfully. The general objectives are:

- Support the communication between users and providers of machine vision systems.
- Help users and providers to specify the task and the solution.
- Avoid communication problems during planning, implementation, acceptance test etc.
- Strengthen the confidence in machine vision systems and open new applications for machine vision systems.

VDI/VDE 2632 Part 1: Basics, terms, and definitions

Knowing what you are talking about is the start of every successful project. The standard describes the principles and defines the terms necessary for the use of machine vision systems. It defines a consistent terminology for all cooperation partners, e. g. illumination types. Part 1 was issued in April 2010 (German/English) and most recently updated in 2021.

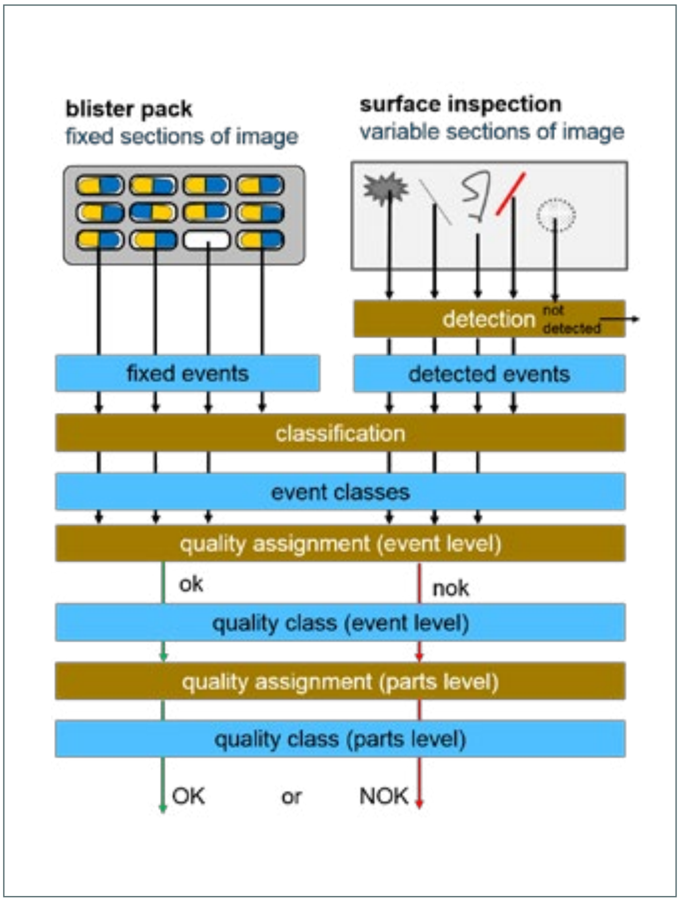


G3 Standard: VDI/VDE/VDMA 2632 Part 2: Guideline for the preparation of a requirement specification and a system specification

The standard aids in the preparation of specifications for industrial machine vision systems. Emphasis was placed on the representation and description of influencing factors as well as on their effects. The project partners are thus able to identify influences at an early stage during planning and to find optimized solutions. Part 2 was issued in September 2015 (German/English, since April 2017 also in an English/Chinese edition) and is an accepted G3 Standard.

VDI/VDE/VDMA 2632 Part 3: Acceptance test of classifying machine vision systems

For measuring (non-classifying) machine vision systems, quantitative capability analysis is already well established. Measurement uncertainty is usually employed as an indicator. Until now, on the other hand, there have been no correspon-ding and accepted qualification indicators for classifying machine vision systems whose results are attributive variables. Part 3 closes this gap and introduces indicators describing the classification capability of a machine vision system. Part 3 was issued in October 2017 (German/English).



Additional parts

The following parts cover further topics:

- VDI/VDE/VDMA 2632 Part 3.1: Acceptance tests of classifying machine vision systems - tests of the classification performance. Issued in August 2020.
- VDI/VDE/VDMA 2632 Part 4.1
Surface inspection systems in flat steel production - Stability testing. Issued in August 2020.

Source of supply

The VDI/VDE/VDMA 2632 series of standards can be purchased at Beuth Verlag (www.beuth.de/en) in print or as PDF files.

More Info at
https://bit.ly/2EksmCI