Application Note

Integrating an Automation Technology 3D camera

Date	*March 14, 2017*
Author	*M.Lingenfelder*
Revision	*1.0*

This document aims to give recommendations towards the setup of Automation Technology 3D cameras on a general basis, while also addressing commonly asked questions regarding the installation itself or certain features of the device. As most of the information contained herein has been of practical interest in the past, it has been verified to work accordingly. Please note that the document is intended as supplementary to the documentation already provided by Automation Technology. If in doubt, the manufacturer should be considered as the authoritative source of information.

Our mission is to provide the users and developers of imaging technology with competitive advantage by adding value in the supply of quality components, world-class vision expertise and support. With this manual we want to help you to get your imaging system up and running as quickly and easy as possible – to strengthen the competitive advantage of your company.

Contents

1 Basic Configuration

1.1 Software Packages

The AT 3D cameras can be configured in several ways. However, the easiest way is to use the camera manufacturers configuration utility, the CXExplorer. Generally, there is no limitation towards the imaging SDK used, unless it lacks proper support for the two industry standards *GigEVision* and *GenICam*.

As *Stemmer Imaging* has no indication about the practical compliance of other SDK products regarding the before mentioned standards, we recommend using our AIA-certified *Common Vision Blox (CVB)* implementation, which has been proven to be highly reliable. For this reason, we will mention CVB in the following, while there is of course the possibility of using other SDK products instead.
The stages of image acquisition and image processing can of course also be handled by distinct SDKs. That way, a *GigEVision/GenICam* capable SDK can be utilized for the acquisition task, while the images are directly handed to another processing SDK in the next step.

Please note that the 3D cameras, the CX-Explorer software as well as CVB are still subject to continuous development, as the technologies around them still evolve. We recommend using the most current software available if you start out with integrating the camera. Don't hesitate to approach us if you have any questions regarding this topic.

1.1.1 CX Explorer

The CX-Explorer is a graphical application to configure C4 sensors, developed by the camera manufacturer, Automation Technology (AT). As the 3D cameras are *GigEVision/GenICam* compliant, they can theoretically be configured by any application supporting these industry standards. However, the CX-Explorer has special views and functionality tailored for exactly this type of camera. This makes it very handy for configuring an initial setup, quickly change configurations and looking at the practical consequences of differences in parameter sets.

Since the CX-Explorer is using the *GigEVision* Transport Layer developed by *Stemmer Imaging*, at least the runtime setup of *Common Vision Blox* has to be installed to run it properly.

The CX-Explorer is a proprietary application, free of charge and can be obtained from the download area of the website of Stemmer Imaging.

1.1.2 Common Vision Blox

Common Vision Blox is an image processing SDK, developed by Stemmer Imaging, which provides a variety of tools specialized on industrial vision applications. It has support for a considerable number of popular programming languages, e.g. C++, .Net, Delphi7, BorlandC++.

Its architecture is based on a layered model: At the base, there's a low-level part entirely dedicated to the integration of imaging hardware and basic data acquisition tasks. This is the CVB Image Manager. A level above are the CVB Tools, a collection of specialized algorithms for the majority of image processing tasks currently conceivable. Both layers can be used individually.

The CVB Image Manager features a complete implementation of the GigEVision protocol. Furthermore, it comes with a GenICam API that's particularly easy to handle. These two building blocks are already sufficient to develop a GigEVision application and to communicate programmatically with a GenICam device.

To support our customers optimally in developing their applications, a CameraSuite license is included with every GigEVision camera bought at Stemmer Imaging. CameraSuite is a license that allows the usage of any Image Manager functionality as long as the camera is connected via Ethernet.

1.2 Networking

It is crucial to correctly set up a number of networking parameters when using the high performance 3D cameras (and GigEVision cameras in general), in order to guarantee the expected performance.

Please note that the network interface card has to be Gigabit Ethernet capable. Otherwise, the data rate will be inferior and images will show defects in triangulation mode; we discourage using onboard-interfaces and recommend Intel I350 Server Adapter models due to reliability reasons. As for the wiring, please use shielded Ethernet cables (at least CAT5E).

Also note that the maximum cable length depends on the wire quality and cable routing. An error free transmission can be expected for less than 30 meters in the absence of excess electro-magnetic interference (EMI) noise. The nominal length of 100 meters however usually requires also high quality cabling.

1.2.1 Network Interface Configuration

These parameters are accessible via the network interface configuration utility on the host machine. Please keep the following general things in mind:

- Firewalls and VPN drivers are also hooked in below the socket layer, thus they can potentially interfere with other filter drivers. Please shut them down for the NIC in question.
- Any other services on the network card take resources. To operate a GigEVision device, nothing beyond the siFilterDriver and TCP/IP v4 is necessary. If possible, any other services, clients or protocols should be deactivated.
- Windows supports up to 14 filter driver instances, of which 8 are activated by default in the system registry. Even if a number of filter drivers below the maximum is installed, new drivers might not work due to the fact that some filter drivers are not visible to the user. If in doubt, please increase the registry variable `HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\Network\MaxNumFilters`

For the configuration of the network card itself, these parameters are of importance:

Jumbo Frames	9014 Byte
Interrupt Moderation Rate	Extreme
Receive Descriptors	2048
Transmit Descriptors	2048

The network interface on the host machine can be either configured with a static IP address or by “Dynamic Configuration”. This generally follows the same procedure as the camera address assignment (see below).

1.2.2 Camera Address Assignment

There are several modes of negotiating a network address and range between a camera and the host machine. Whether a static assignment or DHCP (see below) is to be used can be chosen individually. Upon delivery, the AT 3D cameras are factory preset with “Static IP” enabled, and DHCP disabled. The statically assigned IP is 169.254.64.2 with a netmask of 255.255.0.0, ie. /16 in CIDR notation. Note that choosing this address from the LLA range is intentional.

a) static address assignment

If the camera has a static address assigned, it will stop at this stage. Static addresses must be explicitly assigned by a user via the GenICam grid or an API. In case connecting to a camera is not possible anymore due to a misconfiguration of either host or camera, the GenICam Browser of Stemmer Imaging provides a possibility to force a temporary IP address on the camera. This way, it is accessible again and allows to change the camera parameters.

b) dynamic host configuration protocol (DHCP)

If the camera does not detect a static setting, it tries to query a DHCP server on the network. This is a broadcast message, which is answered by an adequately configured server on the network, which then provides the camera with an IP address.

c) link lical addressing (LLA)

In general, if no answer from a DHCP server is reaching the camera for 60 seconds, it ceases querying and configures its interface via the LLA approach. This includes choosing a random address from the 169.254.0.0/16 subnet range, checking its availability via an Address Resolution Protocol (ARP) query and assigning it to itself. As LLA is the factory state of the AT 3D sensors, the camera should initially be directly connected to an Ethernet interface which is set to dynamic configuration. After a maximum of 60 seconds the interface configures a LLA address and is able to initiate a connection to the camera.

1.2.3 Camera Network Efficiency Parameters

Please change the following parameters via the GenICam Grid, which is accessible through the AT CX-Explorer or GenICam Browser. To obtain access you have to enter the Guru visibility mode.

Packet size and Interpacket delay are implemented as volatile values in the camera to prevent connectivity problems due to a saved configuration. They are both lost at power-off. It is necessary to set the below parameters after every reboot of the camera. This can be either accomplished automatically by the CVB driver (see below), programmatically with the GenApi or manually via the GenICam Grid.

Interpacket Delay	2000
Packet Size	8192 Byte

In case of corrupted frames an increasing of the inter-packet delay is suggested. A lowering of the value might be necessary when the data rate is insufficient.

1.2.4 CVB GenICam Driver Configuration

The CVB GenICam driver can be configured to propagate the above settings to the device at driver loading time. It also has capabilities to determine these parameters automatically by querying the device. We however recommend to set them statically in case of non-default configurations. Additionally, the driver has some more parameters, which don't affect the camera operation. Most importantly for the AT 3D cameras, the incoming image colour mode must be set.

To modify the respective values, open the file GenICam.ini, which is to be found in the Drivers directory of your CVB installation.

Color Mode	Raw
Packet Size	8192
Interpacket Delay	Default value is sufficient for standard use case, but can be reduced

The interpacket delay is usually specified in GenICam TimestampCounterTicks, which commonly differs between camera models. As this differences would be misleading when operating with different AT sensor models, AT decided to base the tick on a 100 MHz clock. Thus one tick is 10 ns.

1.2.5 Further Documentation

There is additional information available regarding networking topics, which might be of interest to some users.

- The CVB setup comes with an extensive user guide on GenICam (`GenICam_CVB_UserGuide.chm`). This document is located within the CVB root directory in the documentation path
- For persons interested in the GenICam standard itself, the EMVA GenICam standardization group offers documents on its webpage at
  `http://www.genicam.org`
- Further information on GigE Vision is available at the AIA site at
  `http://www.machinevisiononline.org`

1.3 Triggering

There are several ways to trigger the AT cameras.

1.3.1 Trigger Inputs

Profile triggering of the AT 3D devices can be performed via the RS-422 encoder interface or opto-coupled inputs IN1 and IN2 on the I/O panel (TTL, 5 or 24 V).

ProfileTriggerMode •	IEnumeration	RW	Beginner	Configure profile trigger mode (1): FreeRun (Value= 0) (2): CameraInput1 (Value= 1) (3): CameraInput2 (Value= 2) (4): EncoderResolverInterfaceRS422 (Value= 3)

Figure 1: Profile Trigger Mode

Frame trigger signals can exclusively be fed over inputs IN1 or IN2.

SequencerMode •	IEnumeration	RW	Beginner	Configure sequencer mode (1): FreeRun (Value= 0) (2): StartStopCameraInput12 (Value= 1) (3): StartCameraInput1 (Value= 2) (4): GateCameraInput1 (Value= 3) (5): StartStopCameraInput12Event (Value= 5) (6): AutoStart (Value= 6)

Figure 2: Sequencer Trigger Mode

Please note that this implicitly prevents using an external frame trigger when the profile/line trigger is input on the digital I/Os. If both trigger types should be provided externally, a rotary encoder is necessary. To fully exploit the available capabilities of the 3D cameras, a 24 V quadruple encoder is recommended, i.e. providing two pairs of differential outputs, signalling forward and backward movement. However, a single RS-422 pair can be used as well. The shield of the encoder should be connected to the input ground clamp.

1.3.2 Maximum Input Trigger Frequency

The maximum frequency the input opto-coupler can handle for RS-422 as well as TTL and 24 V DC is 5 MHz. Please be aware that incoming profile trigger signals can be divided internally. The divider field has a size of 32 bit.
TTL or 24 V DC trigger signals must be connected to digital input IN1 and IN2 instead of the RS-422 clamp row.

1.3.3 RS-422 Encoder Triggering

The trigger occurs on every edge of the RS-422 encoder signal, both on rising and falling edges. The trigger frequency can be reduced by means of a trigger divider (32 bit), e.g. a value of trigger divider equal to 2 means that every second edge will be used to generate a profile / line trigger. This is done by loading the value of trigger divider into an internal counter of the camera after starting the frame acquisition. For every incoming edge of the RS-422 encoder pulse, the internal counter is decreased by 1. As soon as the internal counter reaches zero, a profile/line trigger is generated.

TriggerDivider •	IInteger	RW	Beginner	Trigger divider Min: 1 Max: 65535 Increment: 1
TriggerCoord	IInteger	RO	Beginner	Trigger coordinate
TriggerDirectionMode	IBoolean	RW	Beginner	Count resolver pulses in both directions
TriggerReverseDirection	IBoolean	RW	Beginner	Reverse the resolver count direction
TriggerSingleChannelMode •	IEnumeration	RW	Guru	Enable resolver in single channel mode (1): Disabled (Value= 0) (2): EnableIn1 (Value= 1) (3): EnableIn2 (Value= 2)
TriggerDividerLoadAtStart •	IBoolean	RW	Beginner	Load trigger divider upon start trigger
LoadTriggerDivider •	ICommand	RO*	Beginner	Load trigger divider
ClearTriggerCoord	ICommand	RO*	Beginner	Reset trigger coordinate

Figure 3: RS-422 Encoder Parameters

The RS-422 encoder triggering can be bi-directional or direction. In the latter case the triggering direction can be defined. If the RS-422 pulse direction "runs" in the opposite direction against the defined triggering direction, then the internal counter is increased by 1. This functionality (supported by firmware 1.3.0 and later) guarantees that only one profile/line trigger can be generated per encoder position.

When using the Start/Stop sequencer mode, the trigger divisor can be configured to be loaded automatically after each Start signal. Furthermore, firmware 1.3.0 and later features an encoder coordinate counter, which counts all incoming encoder pulses, and is thus providing information about the current position of transport system.

Multiple RS-422 consumers

There are cases, in which a single source RS-422 signal has to be propagated to drive more than one camera. However, RS-422 is designed for point-to-point communications only. Any soundly manufactured RS-422 consumer employs input termination to stabilize the signal level (C4: 100 Ω, rated at 25 mA at 2.5 V).

A simple cabling solution might work for e.g. two devices, but will already lead to signal degradation due to the dual termination, which halves the signal level. A daisy-chain approach might yield better results than a Y-cable from a reflection point of view. Depending on the devices driven, this can work. But as it is outside of any specification, practical validation is essential. Removal of termination resistors is strongly discouraged, as this will seriously impair the signal reception properties.

There is still an alternative solution with cabling only, for a dual camera setup: The first camera is fed by the encoder signal and yields an “IntegrationActive” signal on its output. This output is connected to the input of the second camera, using the TTL input as a line trigger.

Though cabling solutions are possible, we do not recommend them. We strongly suggest the use of RS-422 splitter devices in those cases, as offered by e.g. `http://www.motrona.com`. This is the cleanest and reliable way to distribute RS-422 signals to several consumers.

1.3.4 Software Trigger

The AT 3D cameras provide the opportunity to trigger profiles and frames using trigger pulses generated by a software. Therefore, the same settings as for a hardware triggered acquisition must be configured. Signals can then be artificially generated by the camera itself and internally used as hardware triggers using the following commands within the camera grid: *StartPulse, StopPulse, TriggerPulse*

StartPulse	ICommand	WO	Beginner	Send start pulse
StopPulse	ICommand	WO	Beginner	Send stop pulse
TriggerPulse	ICommand	WO	Beginner	Send trigger pulse
RstFrameCnt	ICommand	WO	Beginner	Reset frame counter to zero
SearchAoi **	ICommand	WO	Beginner	Fit AOI to laser line position. Supports only one AOI!

Figure 4: Software Trigger

Since the SW triggers use the same configuration as the HW triggers, sending test commands for triggering can be a good way for error handling regarding trigger issues.

1.3.5 GenICam

There are a number of different modes to control the capturing of height image frames. The signal responsible to trigger the integration of a single “line” can originate from the camera or an external source and will not be subject to this discussion. It is assumed that either one of them is present. The number of height images to acquire can be either defined statically or set dynamically.

a) static count

A static number of images implicitly predefines the point where the acquisition ends. Therefore, it doesn’t make sense to supply more than one external signal (i.e. the one that starts the acquisition).

Two camera parameters influence the number of height images to be captured. These are listed below the "Acquisition Control" section.

Acquisition Mode	Defines the automatic stop of the frame acquisition without an external hardware signal. Choices are *Continuous, Single Frame, Multiple Frame*
Acquisition Frame Count	Number of frames to capture in Multiple Frame Mode

Acquisition Mode: Defines the automatic stop of the frame acquisition without an external hardware signal. Choices are Continuous, Single Frame, Multiple Frame Acquisition Frame Count: Number of frames to capture in Multiple Frame Mode
It is obvious that only the last two acquisition modes are useful in this context. Note that *Single Frame* and *Multiple Frame* with *Acquisition Frame Count* equal to 1 yield the same result, though internally they work differently. Please use the former version if you intend to take only one height frame per trigger. The second variant is intended for semi-dynamic changes of image numbers by software.

b) dynamic count

In case the number of images depends on external conditions (e.g. potentially varying size of an object), a dynamic acquisition mode should be preferred. For those modes, the parameter *Acquisition Mode* (see above) should be set to *Continuous*.

c) sequencer mode

The sequencer modes are used to synchronize the start of a frame acquisition - and optionally stop the acquisition - by an external hardware signal. For this purpose, the opto-coupled digital inputs on the I/O breakout board of the camera are utilised, which can be fed by either TTL or 24 V DC.

The following is an overview over the Sequencer Modes ("Frame Trigger Controls") available. Not all of them are suitable for both types of acquisition. To trigger images, the following values for parameter can be selected:

- **Start/Stop over camera input 1/2:** A signal is expected on camera input 1, starting the continuous acquisition of frames, while a signal on input 2 will stop the acquisition. Both inputs trigger on detection of a rising edge (TTL). Upon reception of the stop signal, the current frame is completed before sent to the host. When a fixed number of images is given, the acquisition stops after that number of images, even when no stop signal is sensed.
- **Trigger one frame over camera input 1:** A start signal is expected on camera input 1, triggering exactly one frame to be acquired. The input triggers on detection of a rising edge (TTL). This mode is equivalent with all other sequencing modes in combination with Acquisition Mode: Single Frame (see below).
- **Gate over camera input 1:** After a HIGH level has been detected on input 1, images are continuously acquired until the voltage level is going back to LOW. When detecting the LOW level, the current frame

is completed before sent to the host. When a fixed number of images is given, the acquisition stops after that number of images, even when HIGH signal is still present.

- **Start/Stop with instant transmission over camera input 1/2:** A signal is expected on camera input 1, starting the continuous acquisition of frames, while a signal on input 2 will stop the acquisition. Both inputs trigger on detection of a rising edge (TTL). Upon reception of the stop signal, the current frame is immediately sent to the host. The frame will have the same size as its predecessors, invalid lines are however filled with random content. The actual number of valid lines can be determined either via Chunk data or the “sizey” parameter. When a fixed number of images is given, the acquisition stops after that number of images, even when no stop signal is sensed.

2 Exemplary Setup

The configuration of a AT 3D device is accomplished in two roughly distinct stages. While the first one deals mainly with physical configuration, the second one is entirely dedicated to the camera software settings.

2.1 Components

The first stage comprises the setup steps like choosing a triangulation angle, assembling the components, positioning the sensor and the laser, focusing the lens and finally, getting an optimal laser line interpretation on the sensor.

2.1.1 Choosing a Triangulation Geometry

The foremost question on any laser triangulation task is the geometric configuration of laser and camera. Depending on their orientation, certain advantages for a particular type of inspection can be exploited, usually at the expense of some less important property. The possible choices regarding the triangulation angle are discussed in the sensor hardware manual. In practice, the most common setup is a 30° angle between camera and laser, where the laser is orientated perpendicular to the object plane.

2.1.2 Mounting

The main components should be firmly mounted with correct angle and distance. Refer to the laser manual, respectively the lens specification for correct focal lengths. To prevent excessive sensor temperatures, affixing the sensor on a heat-conductive mount is recommended.

2.1.3 Starting the CX Explorer

Both, laser and camera should be powered up. When connected it is possible to access the camera in the AT CX-Explorer. The camera will come up with factory defaults, which is “Image Mode” in full frame configuration. In case the laser is driven from the camera rear plug or a compact sensor is used, it must be activated by setting the appropriate features in the GenICam Grid. In stand-alone firmware versions the laser must be handled within the “CameraIO” section, compact sensors contain a specific section which is called “LightControl”.

The AT camera series have different ways to control a laser using the GenICam grid:

C5 Series

Using a laser with a C5 the laser must be connected to one of the two Outputs of the camera. The available conditions for the Output (section: *CameraIO*) will directly influence the behaviour of the laser:

Integration Active	turns laser automatically on/off during sensor integration
Sequencer Active	turns laser automatically on/off during sensor integration
Integration Dual Slope Active	
Integration Triple Slope Active	
High	turns laser on
Low	turns laser off
Internal Trigger	turns laser automatically on when internal trigger is high
Sequencer Trigger Active	turns laser automatically on when sequencer trigger is active

C5-CS Series

Controlling the laser of an AT compact sensor, an additional section in the GenICam Grid, the *Light Control*, is existing. Following parameters can be set there:

Integration Active	turns laser automatically on/off during sensor integration
Sequencer Active	turns laser automatically on/off during sensor integration
Integration Dual Slope Active	
Integration Triple Slope Active	

C2 / C4 Series

Using a laser with a C2 or C4 and the corresponding I/O panel, the laser can be controlled using the available settings in the *CameraIO* section of the grid.

Laser Power	Sets the output analog voltage of the laser
TurnLaserOn	turns laser on/off
TurnLaserOnAuto	turns laser automatically on/off during sensor integration

2.1.4 Optical Filters and Scheimpflug Adapter

There are two common optical options to improve the image quality in a triangulation setup. If neither is relevant for the application, this paragraph can be skipped. The simplest one is to use a bandpass filter to decrease the influence of ambient light. This is relatively effective due to the near-monochromatic properties of laser illuminations used for triangulation. If you intend to use lenses with small F-values (< 25 mm), note that blueshift can occur at the corners of the lens. It might then be necessary to place the lens on top of the filter instead vice versa. Please contact us in case you're unsure if you're affected.

However, ambient white light sources usually still emit a certain amount of light within the wavelength in question. The effect of this stray illumination must be countered by closing the aperture as much as possible or by protecting the whole installation from exterior light sources. It goes without saying that the maximum possible aperture reduction is proportial to the lasers intensity. Thus the said effect is decreasing with using higher laser intensities.

Another measure to get an improved (i.e. sharper) line representation on the sensor is using a so-called Scheimpflug adapter. Any lens has a distinct plane where the optical imaging is optimal, depending on its focal length. Thus the imaging of object becomes gradually less sharp below and above that plane. As inspection objects commonly have features of different height, the laser line can only be imaged optimally at one height level, while the sharpness of the remainder is more or less satisfactory.

The usage of a Scheimpflug adapter (also known as Tilt-Shift objective) counters this behaviour by tilting the lens plane relative to the sensor plane in a certain angle, which leads to a maximum sharpness in the plane of the laser sheet. The Scheimpflug angle can only be calculated if the triangulation angle and horizontal distance between laser and camera are known.

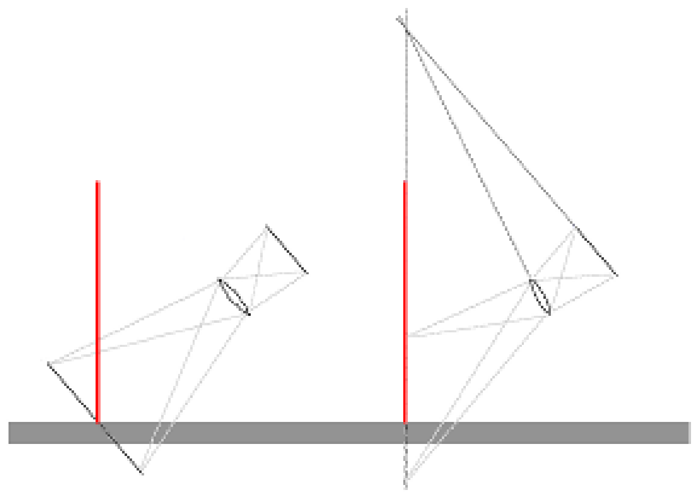

Figure 5: Normal camera lens setup (left), Scheimpflug arrangement (right)

2.1.5 Laser and Lens Alignment

To adjust the camera optics and the laser/led laser line, the aperture should be opened to a maximum first. This aids in focussing the object plane, since differences in sharpness are much more visible. The lenses are best focussed when the laser line has the smallest possible line width. This can be easily checked with the line profile histogram available in the CX Explorer. Please remember to activate the 16-bit mode to obtain a well resolved histogram.
When the image and the laser line are sharp at the imaging area, the focus ring of the camera lens is best affixed by using the screw within the ring.

After finding the ideal focus of lens and laser, the aperture should be reduced again. Finding an appropriate aperture setting is crucial for a good triangulation system. Wide and narrow apertures have following different

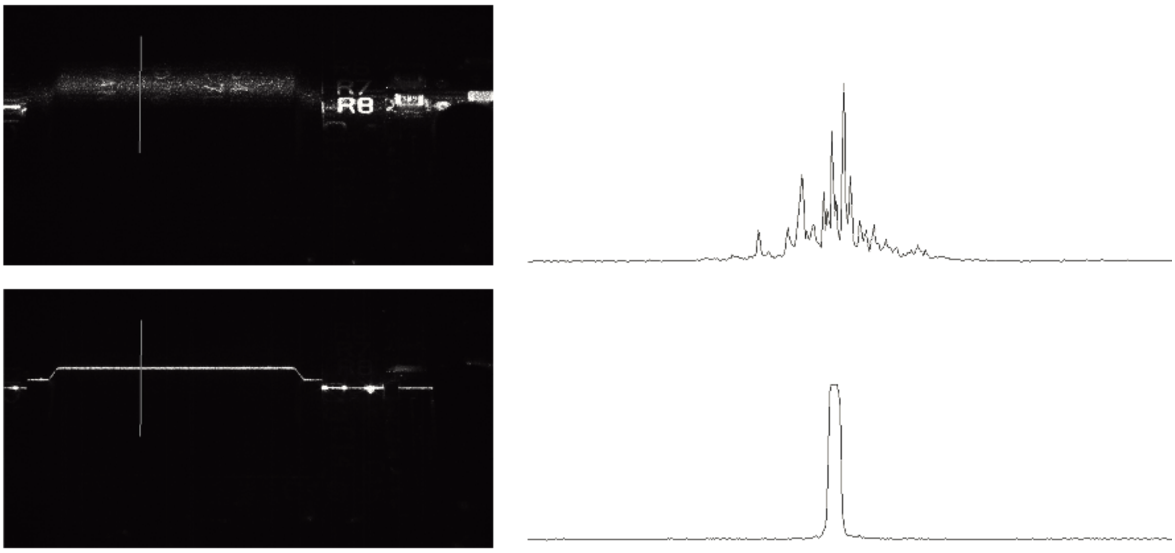

Figure 6: Laser sharpness with vertical histogram (defocussed in first, focussed in second image)

advantages which should be taken into account when setting up the system:

Wider aperture

- Reduces interference from laser speckle

Narrower aperture

- Better depth of field (in case of the usage of a Scheimpflug adapter, this is neglectable)
- Removes unwanted artefacts caused by exterior lighting

Experiences show that normally a good compromise can be found when narrowing down the aperture about two increments.

Nothing except the laser line should be visible at this point. Whether still enough intensity is received by the sensor can be easily checked with the above mentioned profile mode provided by the CX Explorer.

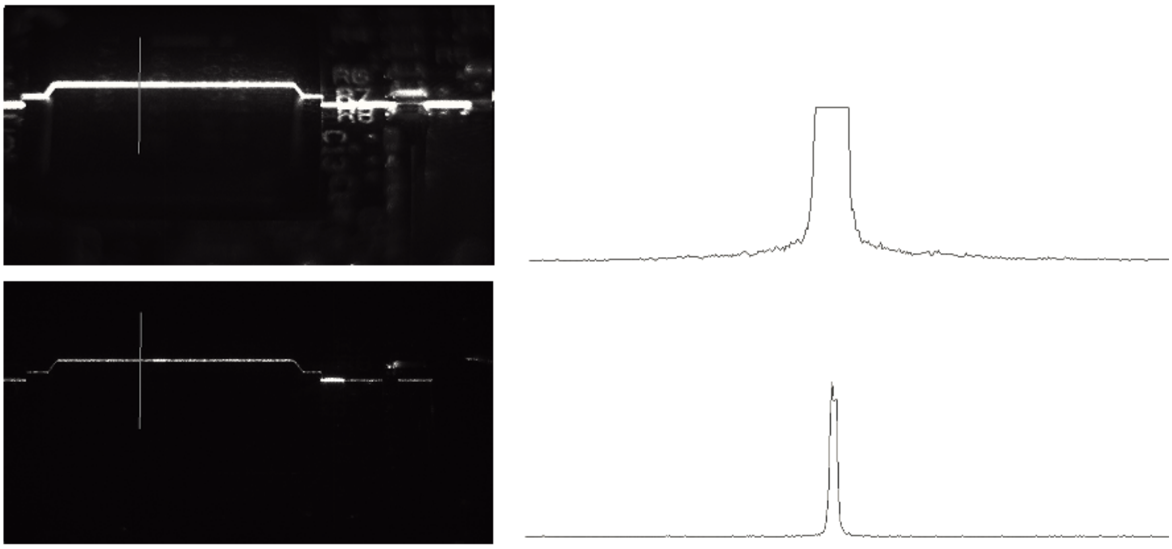

Figure 7: Lens aperture with vertical histogram (wide open in first, reduced in second image)

2.1.6 AOI Selection

As a last step, the number of pixels to read out should be reduced by choosing an appropriate Area Of Interest (AOI). This is important, since the readout time is linearly related to the size of this area. To do so, start the acquisition and move a sample object under the laser line. Then pick the rectangle tool from the top toolbar of the CX Explorer and choose an area which fits the size of the object to capture. Stop acquiring images and click the AOI button on top. Now the AOI is set and will be applied from the next time on when an image is acquired.

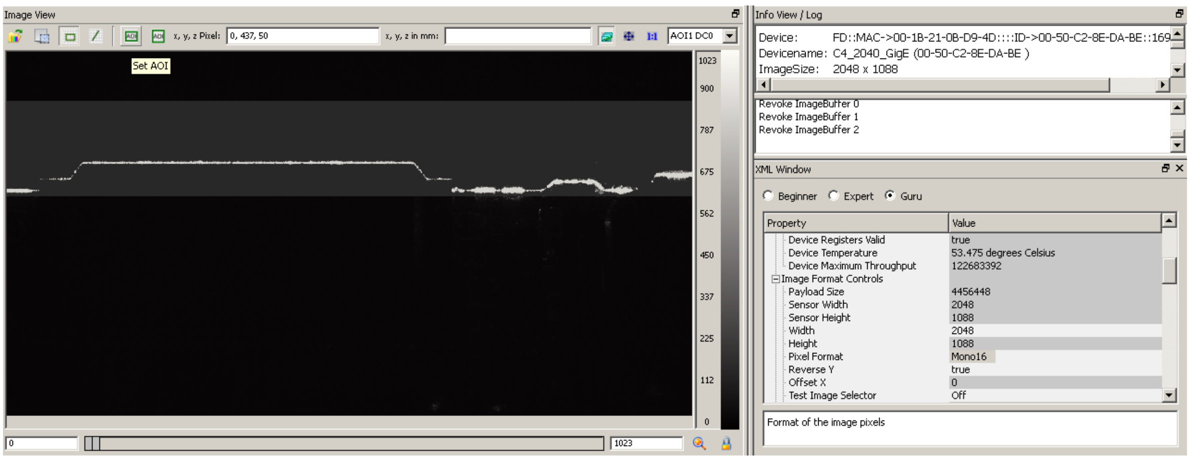

Figure 8: CX Explorer AOI Selection

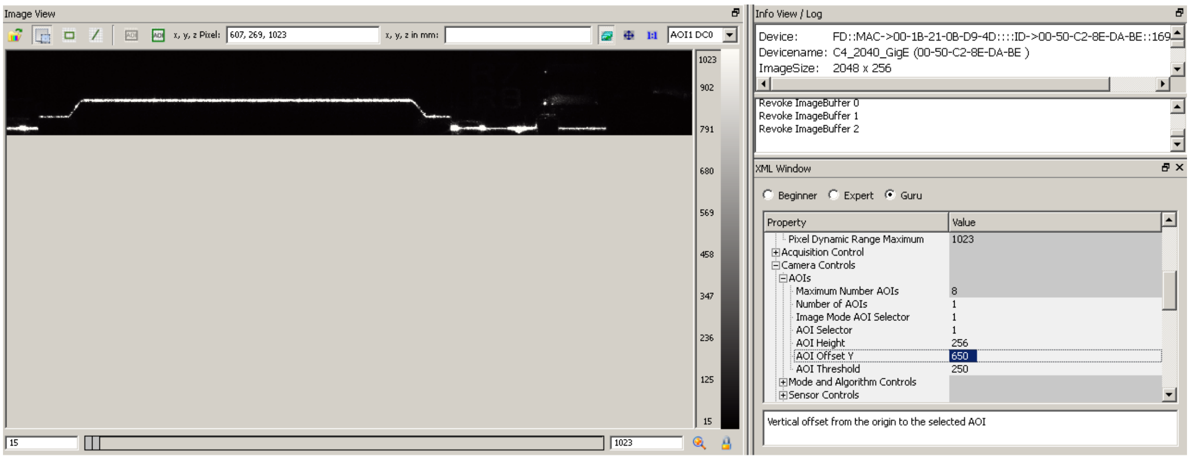

Figure 9: CX Explorer with selected AOI set

With the implementation of the above mentioned steps, the primary setup stage can be considered finished.

2.2 Data Acquisition

For the second stage, all hardware related setup is assumed to be done. The subsequent steps deal with the most important actions to transmit a 2.5D height map from the device.

2.2.1 Choosing a 3D Sensor Algorithm

The 3D profile modes specify how the centre of the laser line is determined. All modes are equally fast, thus the one that best suits the application should be selected. The operation mode can be chosen by setting the following parameter: Screenshot

CameraMode •	IEnumeration	RW	Beginner	Selects the camera mode and/or algorithm (1): Image (Value= 0) (2): FIRPeak (Value= 4) (3): CenterOfGravity (Value= 3) (4): Threshold (Value= 1) (5): MaximumIntensity (Value= 2)

Figure 10: 3D Acquisition Modes

The Maximum algorithm **(MAX)** determines the pixel yielding the highest intensity and assumes this as the line's central position. It does not provide any subpixeling, but can be nevertheless useful for inspecting objects with volume scatter.

Of higher precision is the Threshold algorithm **(TRSH)**, which returns the left and right intersection of threshold value and intensity profile as well as the mean value between those. Consequently, the centre is determined with one subpixel of accuracy.

The Centre Of Gravity **(COG)** mode determines the positions with a precision of up to 6 subpixels. It is more robust and resilient than the two previous algorithms. When using the COG approach, the laser line width should cover at least 4 sensor pixels to allow for a meaningful detection.

There is a fourth 3D algorithm available, called FIR-Peak **(FIR)**. This algorithm is based on a zero-detection on the first deviation of the signal and is even more robust against noisy signals. However, this algorithm only works with non-overexposed laser lines. It provides positions also with up to 6 subpixels. The FIR-filter can be the algorithm of choice when used in combination with a multiple slope in order to ensure non-overexposed images.

Furthermore, the FIR-filter can be used in combination with the other algorithms (TRSH, MAX, COG) as a pre-processor for smoothing the sensor image. Therefore, the *FIRMode* must be set to *Smoothing(0)*.

For any new application where the optimal mode is not already known in advance, we recommend to start using the Centre of Gravity algorithm in combination with a smoothing first.

2.2.2 Changing the Acquisition Speed

At this point, the image rate is still configured to the speed used with “Image mode”. To change this, have a look at the “Sensor Controls” section of the GenICam Grid. It denotes the *readout time* (depending on the AOI) as well as the *integration time* (application dependent). The maximum of both is the minimum sensor frame interval time that can be selected.

In free-running mode, its inverse gives exactly the acquired frames per second (FPS). In triggered mode, it determines the least valid delta for incoming trigger signals. Trigger pulses that are received faster are going to be discarded. As the FPS rate is usually responsible for the correct X/Y resolution, this tends to be a value that only can be modified if the speed of the relative movement is changed as well. To keep a correct image ratio, it is advisable to set the conveyor speed and *Sensor Frame Interval* first and afterwards adjust the integration time.

2.2.3 Multiple Slope Mode

The Multiple Slope Mode is a function to increase the dynamic range of the sensor, similar to the commonly known HDR mode. It allows to capture both, very weak and very strong intensity signals at the same time without image saturation, thus enhancing the precision of laser line detection. It is a strong and easy way to improve the quality of the profile line by just twerking some parameters within the camera grid. When having complex objects with different surface structures it might be inevitable to use the multiple slope mode.

Please refer to the *AppNote on the Multiple Slope Mode* for further information, e.g. for an example procedure about how to set the parameters for an appropriate usage of the Multiple Slope. The AppNote can be found in the installation path of the CX Explorer.

2.2.4 Mode and Algorithm Control

Valid Minimum Width and *Subpixel Bits of COG Output* can give a more precise result (assuming COG mode). While the first is useful to tag small noisy spots as invalid (“Position validation at the end of Gauss scan”) when set to 1 or 2, the second increases the resolution of height values.

2.2.5 Data Output Channels

The different output channels (DC’s) contain the measurement information and can be individually selected for the output. While DC0 always transmits the image reflecting the sum of intensities, DC2 produces the height image. The semantics of DC1 is different depending on the triangulation mode and flags chosen.

Camera Mode	FIR	FIRMode	DC0	DC1	DC2
Image	False	-	Sensor intensity	Not used	Not used
	True	Derivative	First derivative of sensor intensity	Not used	Not used
	True	Smoothing	Smoothed sensor intensity	Not used	Not used
MaximumIntensity	False	-	Maximum intensity of Gauss	Position of rising edge of Gauss (PosL)	Position of maximum intensity of Gauss (PosM)
	True	Smoothing	Maximum intensity of Gauss detected in smoothed sensor image	Position of rising edge of Gauss (PosL) detected in smoothed sensor image	Position of maximum intensity of Gauss (PosM) detected in smoothed sensor image
Threshold	False	-	Maximum intensity of Gauss	- Position of rising edge of Gauss (PosL) or - Gauss width (PosR-PosL)	- Position of falling edge of Gauss (PosR) or - Position of Gauss with 1/2 pixel resolution (PosL+PosR)
	True	Smoothing	Maximum intensity of Gauss detected in smoothed sensor image	- Position of rising edge of Gauss (PosL) or - Gauss width (PosR-PosL) detected in smoothed sensor image	- Position of falling edge of Gauss (PosR) or - Position of Gauss with 1/2 pixel resolution (PosL+PosR) detected in smoothed sensor image
Camera Mode	FIR	FIRMode	DC0	DC1	DC2
CenterOfGravity	False	-	Sum of intensity values of Gauss I_s	- Position of rising edge of Gauss (PosL) or - Gauss width (PosR-PosL)	Position of center of gravity of Gauss with $1/(2^N)$ pixel resolution, where N=number of subpixel bits (0-6)
	True	Smoothing	Sum of intensity values of Gauss I_s in smoothed sensor image	- Position of rising edge of Gauss line (PosL) or - Gauss width (PosR-PosL)	Position of center of gravity of Gauss in smoothed sensor image with $1/(2^N)$ pixel resolution, where N=number of subpixel bits (0-6)
FIRPeak	True	Derivative	Zero-crossing slope (Absolute value)	- Index of next sensor row to the left of zero-crossing or - maximum value of intensity first derivative	Position of Gauss peak with $1/(2^N)$ pixel resolution, where N=number of subpixel bits (0-6)

Figure 11: Data Output Channels

2.2.6 Chunk Mode

Additional information to the output channels which include the image data can be accessed using the chunk mode. The chunk data contains information about the states of triggers, timestamps, frame counters, I/Os, AOI sizes, valid image sizes, etc. and will be outputted in the end of each image frame or profile. More information about the chunk mode is available in the sensor manual.

2.2.7 GigE-Vision Events

The AT 3D cameras support a number of events that can be monitored using e.g. a CVB application by means of a callback function. Events provide real time notification on various stages of the acquisition sequence and data transfer.

2.2.8 Miscellaneous Settings

In addition, the following configuration nodes can be of importance and should be at least reviewed. Please refer to the product manual for a more in-detail treatment of the parameters. For some settings there are Application Notes given in the installation path of the CX Explorer.

- **Non-Destructive Readout:** With the NDR mode it is possible to readout up to 4 images at different exposure times. It allows the combination of profile data from different integration levels and it ensures accurate profile data even for difficult surfaces with strong changes in reflectance. The NDR mode is an alternative to the Multiple Slope, however, it is more time-consuming.
- **Multiple Frame Readout Mode:** Similar to the NDR the multiple frame readout mode acquires images with the information of different integration times. All images will be outputted. Since this mode requires a post-processing of the multiple images on the PC it is recommended to use it only if the Multiple Slope is not sufficient.
- **AOI-Search:** In cases where the starting height of a flat object is unknown, it is recommended to use the AOI-Search mode. This mode allows the user to still set a small AOI around the laser line, however in the beginning of each acquisition the laser line will be searched within all of the camera sensor. This ensures a high scan rate within all of the measurement range in Z.
- **AOI-Tracking:** The AOI-Tracking is the dynamic version of the static AOI-Search mode. It continuously tracks the position of the laser line and moves the AOI in the sensor according to the object movement. This ensures a high scan rate within all of the measurement range in Z and is recommended in applications where flat objects with a constant slope in the direction of movement must be inspected.
- **Auto Start:** The AutoStart mode internally simulates a light barrier mechanism without the use of any additional mechanical and electrical components. It automatically detects the object and triggers the image acquisition to scan the whole object. As this requires a constant profile measurement, it is then possible to deliver profile data even out of a history buffer, e.g. data which were captured before the start trigger.

3 Miscellaneous Information

3.1 Operational Specifications

3.1.1 Heat Dissipation

The AT C4 cameras has a fan mounted on its housing, which is connected to the laser output of the camera. The use of this fan is not mandatory. However, if not used, there must be some other method of conveying the heat produced, e.g. passive cooling by properly mounting the device. There are two primary reasons to keep attention on the camera temperature, which is ideally around 45 °C:

- Integrated circuits are increasingly affected by noise with rising temperatures. With imaging sensors, this leads to a decrease of image quality. Visible noise has been observed with this sensor from about 49 °C upwards.
- As a commonly known rule of thumb, the life expectancy of most electrical components decreases by 50% for every 10 °C.

The MTBF (mean time between failures) of C4 cameras is 100'000 hours operating at 20 °C ambient temperature.

The AT C2 and C5 cameras have additional heat sinks available, which can be mounted on the camera and improve the passive cooling of the sensor. In case of temperature issues of the sensor please refer to the sensor manual for the exact operation details.

3.1.2 Flash Memory Wear

The flash memory used to save configurations on the camera within "User Sets" is guaranteed to handle a least 100'000 write-cycles.

3.1.3 Power Supply

The power input of the I/O panel is highly tolerant to voltage variations. The voltage can vary between 10-24 V DC, while a +/- 10% variation is still acceptable. The I/O box is fused with 2 A. The input voltage level is adjustable between 5V and 24V. Be aware that there is an additional manual for the I/O panel of the sensor.

When running the camera without the I/O panel it is highly recommended to carefully read the sensor manuals since no electronic protections are given. Every wrong connection (e.g. with the I/Os) might lead to a total breakdown of the camera!
The input voltage of the camera is 10-24VDC.

3.2 Known Limitations

3.2.1 Working Temperature

Reception of corrupted frames is possible when the camera is not yet at its operating temperature (i.e. roughly 40 °C to 45 °C). This problem only occurs when image acquisition is immediately started after powering up the device. Since the camera's temperature also rises when no images are taken, it is sufficient to foresee a short amount of time after power-on to reach operating temperature. The current temperature can be queried via GenICam. Please note that this normally doesn't apply to cameras that have only been disconnected for a couple of seconds (e.g. cold reboot).

3.2.2 Laser Power

When powering the AT 3D cameras with less than 24 V, the laser output voltage might not reach the required 5 V. This prevents some devices (e.g. the Z-Laser ZM18 series lasers) to work properly.

3.3 Firmware Updates

3.3.1 General

All AT 3D devices shipped by Stemmer Imaging are using the latest firmware version available at the time of delivery. In particular cases though, it might make sense to conduct a firmware update for a given camera later on. Reasons can be functionality upgrades, mitigation of erroneous behaviour or streamlining all devices in an engine to the same version.

Updating firmware is not possible in all cases, as this mainly depends on the hardware revision of the camera. Please ask us before planning an update. It is furthermore critical that updates take place in a particular order, i.e. do not skip intermediate versions.

The cameras' firmwares are generally field upgradable by a simple process. Stemmer Imaging also offers carrying out firmware updates as a service. Though this service is free of charge in case of faulty behaviour, note that upgrading for other reasons is chargeable. If a customer decides to perform an update on his own, Stemmer Imaging can take no liability whatsoever that the device works correctly after the update.

3.3.2 Update Process

Before updating, please backup all configuration data on the device. A firmware update usually erases all memory on the device, thus deleting configurations and User Sets. The AT CX-Explorer as well as the CVB Management Console offer saving and loading configurations to or from files. Both software packages must be installed before starting the update setup of the firmware.

Also it is necessary to properly configure the device with CVB first. This means that the GenICam nodemap can be accessed either by means of the CVB Management Console or the GEV Config Manager.

Please do not proceed beyond this step if the above provisions are not met. As of now, firmware update packages are exclusively available for 32 bit Windows systems (Windows 7, Windows XP). The package comes as a compressed archive, containing all necessary binaries and scripts. To initiate the process, the batch script within the archive has to be executed. It is launching a shell which presents all GenICam devices currently detected by the host. Each device is listed two times, as both the CVB filter driver and the socket driver are queried. It is safe to select the first entry of a device.

After choosing the C4 camera, the update is started and indicates its state in the shell. The end of the process is signalled by a notification. After successfully finishing the update, it is crucial to perform a cold reboot, i.e. un- and replug the power supply. Now backup configurations can be replayed again. Please note that in some rare cases, a configuration cannot be completely played back due to changes in the XML accessibility structure and must be adapted manually.

3.4 Calibration

3.4.1 Lens Calibration

To be done.

3.4.2 Metric Calibration

To be done.

3.5 FAQ

How long does it take to transmit a profile to an application?

Processing time between acquisition of a frame and queuing of a profile in the C4 is < 10 microseconds. Additionally, a GigE Jumbo Packet takes about 72 microseconds transmission time from sender to the host. The time for packet re-assembly is depending on the GigEVision implementation and the image data properties, but can be assumed to be below the TX time.

Why do I loose or aquire too many profiles?

- **Trigger Overrun:** When the incoming trigger signals exceed the maximum scan rate of the current setup, the *Trigger Overrun* flag will be set and triggers will be lost.
- **Signal quality:** Often, signals degrade through ESD noise nearby, defective cables, signal converter, etc. Please measure your trigger signals with an oscilloscope to ensure the I/O device receives clean signals.
- **Trigger Divider:** The camera interprets every edge of the RS-422 encoder signal. Hence, the trigger frequency must be reduced in order to only use each trigger once. This can be done with the parameter *Trigger Drivider* as mentioned in section 1.3.3.

4 Revision Updates

Rev.	Date	Changes
1.0	14.03.2017	Initial Draft

5 Contact

We hope this tutorial was helpful and are looking forward to your feedback. If you have any further questions, please contact our technical support. Additional information regarding imaging can be found on our website.

DENMARK

Telefon: +46 8 555 110 27
E-Mail: support@stemmer-imaging.dk
Web: www.stemmer-imaging.dk

GERMANY

Austria

Telefon: +49 89 80902-200
E-Mail: support@stemmer-imaging.de
Web: www.stemmer-imaging.de

FINNLAND

BALTICS

Telefon: +358 9 43 555 012
E-Mail: support@stemmer-imaging.fi
Web: www.stemmer-imaging.fi

FRANCE

Telefon: +33 1 45069560
E-Mail: support@stemmer-imaging.fr
Web: www.stemmer-imaging.fr

GREAT BRITAIN

IRELAND

Telefon: +44 1252 780060
E-Mail: support@stemmer-imaging.co.uk
Web: www.stemmer-imaging.co.uk

NETHERLANDS

BELGIUM · LUXEMBOURG

Telefon: +31 575 798881
E-Mail: support@stemmer-imaging.nl
Web: www.stemmer-imaging.nl

POLAND

Telefon: +46 8 555 110 27
E-Mail: support@stemmer-imaging.pl
Web: www.stemmer-imaging.pl

SWEDEN

NORWAY · ICELAND

Telefon: +46 8 555 110 27
E-Mail: support@stemmer-imaging.se
Web: www.stemmer-imaging.se

SWITZERLAND

LIECHTENSTEIN

Telefon: +41 55 415 90 90
E-Mail: support@stemmer-imaging.ch
Web: www.stemmer-imaging.ch