GenICam Standard

Generic Interface for Cameras

Version 1.0

http://www.genicam.org/GenApi/Version_1_0

GEN<i>CAM

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HISTORY

Version	Date	Changed by	Change
1.0	13.06.2006	Fritz Dierks, Basler	Released version as voted on during the Montreal meeting

1 Overview

Today's digital cameras are packed with much more functionality than just delivering an image. Processing the image and appending the results to the image data stream, controlling external hardware, and doing the real-time part of the application have become common tasks for machine vision cameras. As a result, the programming interface for cameras has become more and more complex.

The goal of GenICam is to provide a generic programming interface for all kinds of cameras. No matter what interface technology the cameras are using or what features they are implementing, the application programming interface (API) should be always the same (see Figure 1).

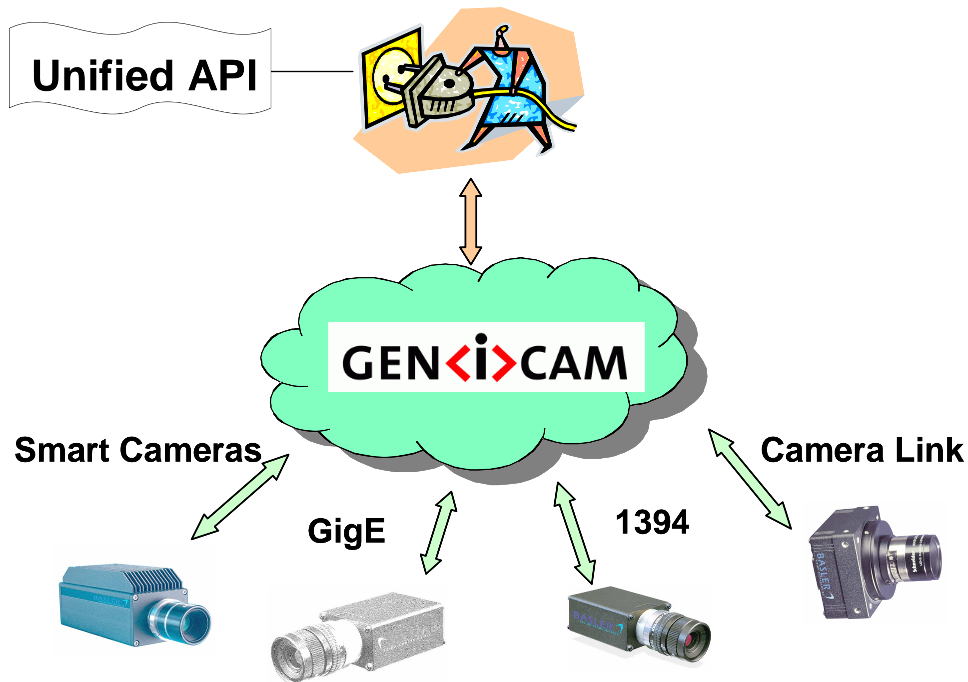


Figure 1 The GenICam vision

The **GenICam** standard consists of multiple **modules** according to the main tasks to be solved:

- **GenApi** : Application programming interface (API) for configuring a camera
- **GenTL** : Transport layer (TL) for grabbing images

The modules can be released independently from each other.

2 GenApi Module – Configuring the Camera

2.1 Introduction

The GenApi module deals with the problem of how to configure a camera. The key idea is to make camera manufacturers provide machine readable versions of the manuals for their cameras. These **camera description files** contain all of the required information to automatically map a camera's **features** to its **registers**.

A typical feature would be the camera's gain and the user's attempt might be, for example, to set *Gain*=42. Using GenICam, a piece of generic software will be able to read the camera's description file and figure out that setting the *Gain* to 42 means writing a value of 0x2A to a register located at 0x0815. Other tasks involved might be to check in advance whether the camera possesses a *Gain* feature and to check whether the new value is consistent with the allowed *Gain* range.

Note that adding a new feature to a camera just means extending the camera's description file, thus making the new feature immediately available to all GenICam aware applications.

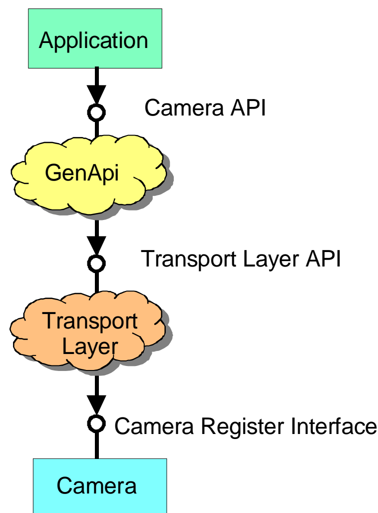


Figure 2 Layers for accessing a camera

Figure 2 shows the layers involved in configuring a camera. The application requires a **camera API** that allows dealing with the camera's features, for example, by writing code which looks like this:

```
Camera.Gain = 42;
```

The GenApi module will translate this call into a series of calls to register access functions provided by the **transport layer API**, for example, like this:

```
TransportLayer.WriteRegister( 0x0815, 0x2A, 2 ); // address, data, length
```

Finally, the transport layer will deliver the calls to the **camera interface**. GenApi currently assumes that the camera is configured using a flat register space.

The GenICam standard defines the **syntax** of the camera description file plus the **semantics** of the transport layer API. In addition, the GenICam standard recommends – but does not enforce – the usage of certain **names** and **types** for common features such as *Gain* or *Shutter*.

The standard does not contain the actual code for reading the description file and translating features to registers, nor does it contain the transport layer code. Everyone is free to do their own implementation. There is, however, a **reference implementation** available that can be freely used.

Note that the **GenApi** section in this document deals with the camera description file only. It is intended to help the GenICam user to understand the key ideas behind the GenApi module and to enable people to write their own camera description files. The GenApi reference implementation comes with a reference manual showing how an end user can use the GenApi module even without a deeper understanding of the concepts laid out in this section.

2.2 Basic Structure of the Camera Description File

The camera is described by means on an **XML file** containing a set of nodes with each node having a **type** and a unique **name**. Nodes can link to each other and each connection plays a certain **role**. Figure 3 shows a very simple example in graphical notation. The nodes are shown as bubbles labeled "type::name," and the links are shown as arrows labeled with the role name.

There are two special nodes: the **Root** node from which one can start walking the node graph and the **Device** node that provides the connection to the transport layer.[1]

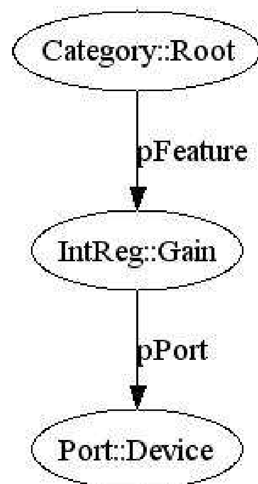


Figure 3 Topology of a graph constructed from a simple configuration file

[1] Note that GenApi can be used to access other register based devices in addition to cameras.

The *Gain* node in Figure 3 is of the IntReg type, which allows the extraction an integer from a register. Looked at from the *Root* node, it is a feature of the camera. The *Root* node, therefore, contains a link named *pFeature* referencing the *Gain* node. To read and write the *Gain* registers, the *Gain* node needs access to the camera port, and thus it contains a link to the *Device* node. The link is named *pPort* and references the *Device* node.

The Gain node contains all of the information required to extract a two byte unsigned integer in BigEndian mode. The complete camera description file looks like this:

```
<?xml version="1.0" encoding="utf-8"?>

<RegisterDescription
  ModelName="Example01"
  VendorName="Test"
  ToolTip="Example 01 from the GenApi standard"
  StandardNameSpace="None"
  SchemaMajorVersion="1"
  SchemaMinorVersion="0"
  SchemaSubMinorVersion="1"
  MajorVersion="1"
  MinorVersion="0"
  SubMinorVersion="0"
  ProductGuid="1F3C6A72-7842-4edd-9130-E2E90A2058BA"
  VersionGuid="7645D2A1-A41E-4ac6-B486-1531FB7BECE6"
  xmlns="http://www.genicam.org/GenApi/Version_1_0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.genicam.org/GenApi/Version_1_0
   http://www.genicam.org/GenApi/GenApiSchema_Version_1_0.xsd">

  <Category Name="Root">
    <ToolTip>Entry for traversing the node graph</ToolTip>
    <pFeature>Gain</pFeature>
  </Category>

  <IntReg Name="Gain">
    <ToolTip>Access node for the camera's Gain feature</ToolTip>
    <Address>0x0815</Address>
    <Length>2</Length>
    <AccessMode>RW</AccessMode>
    <pPort>Device</pPort>
    <Sign>Unsigned</Sign>
    <Endianess>BigEndian</Endianess>
  </IntReg>

  <Port Name="Device">
    <ToolTip> Port node giving access to the camera</ToolTip>
  </Port>

</RegisterDescription>
```

The <?xml> node is a processing element giving hints about the encoding of the file and is always the same.

The <RegisterDescription> element is the outermost bracket encapsulating all nodes of the camera. The camera is identified by the *ModelName* and *VendorName* attributes (model

“Example01” from vendor “Test” in this case). The other attributes are explained later in section 2.7.

Inside the <RegisterDescription> element, the nodes are lying in a flat order. Each node has a unique **Name** attribute and can be linked by sub-elements named **p**Role containing the *Name* of some other node.

Each node has an optional <ToolTip> element that contains a short description. The *Gain* node has additional elements that depend on its actual *IntReg* type and tells us, for example, the *Address* of the register or its *Length*.

Typically, an implementation will create one software object per node and will link these objects together according to the logical links described in the XML file.[2] The nodes can either be retrieved by their (unique) name or can be found by traversing the node graph starting with the root node. Once the user has a pointer to the node, he can access that feature through the node object's programming interface.

The syntax of the XML file is defined in the **XML schema** given by the *schemaLocation*-attribute. The schema is part of the standard. This document explains the ideas and overall structure of GenICam. The schema and its embedded reference documentation describe the formal details. In case of doubt, the schema’s content overrides the content of this text.

The file location http://www.genicam.org/GenApi/GenApiSchema_Version_1_0.xsd is mandatory for the camera configuration file but can be overridden at runtime.

2.3 Nodes, Interfaces, and Abstract Features

Each **node** in the camera description file describes a single item. Depending on the item’s nature, the node is of a specific **node type** and has a specific **interface**. The following interfaces are currently available[3] (each one is given with the typical widget used to map it on a graphical user interface):

- *IInteger* – maps to a slider with value, min, max, and increment
- *IFloat* – maps to a slider with value, min, and max plus a physical unit.
- *IString* – maps to an edit box showing a string
- *IEnumeration* – maps to a drop down box
- *ICommand* – maps to a command button
- *IBoolean* – maps to a check box
- *IRegister* – maps to an edit box showing a hex string
- *ICategory* – maps to an entry in a tree structuring the camera's features
- *IPort* – maps to the camera port and is typically not shown graphically

[2] The actual implementation may split some of the XML nodes into a set of multiple implementation nodes.

[3] This list contains only interfaces representing a specific type. The reference implementation contains more interfaces.

The signature of the interfaces is given in more detail in section 2.9. The available node types are described in section 2.8. There might be multiple **node types** implementing the same **interface type**. The *IInteger* interface, for example, is (among others) implemented by the following node types:

- *IntReg* – extracts an integer lying byte-bounded in a register
- *MaskedIntReg* – extracts an integer packed into a register, e.g., from bit 8 to bit 12
- *Integer* – merges the integer's value, min, max, and increment properties from different nodes

Each node type extracts an integer from different sources in a different way. The output of all of these nodes, however, can be used as type-safe input for all links where an integer is required.

Abstract features are always described in terms of an **interface type**, a **name**, and a **meaning**. For example, the *Gain* (name) of a camera might be defined as an *IInteger* (interface type) and might describe the amplification inside a camera (meaning). Note that other possible definitions exist, e.g., the *Gain* could be defined as an *IEnumeration* or as an *IFloat*.

2.4 Getting and Setting Values

When the user reads or writes the value of a node, this node will trigger a cascade of read and write operations within the node graph. To illustrate this, Figure 4 shows a more elaborate example for the *Gain* feature. The *Gain* feature is exposed via an *IInteger* interface that lets the user get and set the feature's *Value* and lets her read (among other things) the feature's *Min* and *Max* value. The example in Figure 4 assumes that the camera has three registers, one for the Gain *Value* itself, one for its *Min* value, and one for its *Max* value. From each of these registers, the corresponding value is extracted using an *IntReg* node. The *Integer* node with the name *Gain* then collects the data and merges them, exposing the results with an *IInteger* interface.

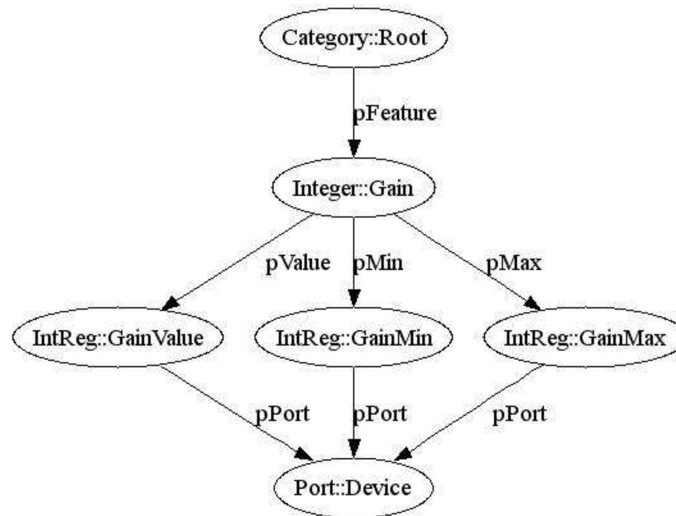


Figure 4 Example of the control flow when getting and setting features

If the user reads the value of the *Gain* node, the call will be dispatched to the *GainValue* node, which will in turn use the *IPort* interface from the *Device* node to ask for the right register.

If the user attempts to set the value of the *Gain* node, the implementation might decide to check the range first by reading the *Min* and *Max* values from the corresponding *GainMin* and *GainMax* nodes. If the value is inside the allowed range, the *Gain* node then will write it via the *GainValue* node and the *Device* node to the camera. Note that the implementation might cache the Min and Max values depending on the *Cacheable* attribute of the corresponding IntReg nodes.

2.5 Access Mode

Each node has an **access mode** defined according to the following table:

Readable	Writable	Implemented	Access Mode
*	*	0	NI – not implemented
0	0	1	NA – not available
0	1	1	WO – write only
1	0	1	RO – read only
1	1	1	RW – readable and writable

1 = yes, 0 = no, * = don't care

A feature may be implemented in a camera, but be temporarily not available. If it is available, then it is, by definition, also implemented and may be readable and/or writable.

Some nodes have elements to control accessibility, for example, the register node (see section 2.8.3). In addition, GenICam provides three mechanisms to change the accessibility at runtime:

- A feature can be temporarily **locked** depending on the value of another node. While locked, a feature is not writable. In terms of the table above, the writable flag is temporarily forced to 0.
- A feature can be temporarily **not available** depending on the value of another node. In terms of the table above, the writable and the readable flags are temporarily forced to 0.
- A feature can be **not implemented** at all depending on the value of another node. In terms of the table above, the implemented flag is permanently forced to 0.

The distinction between being available and being implemented has been made because a GUI might want to handle the two cases differently. A feature being not implemented at all will never be shown to the user and a feature being temporarily not available will be grayed out and the value will be replaced, e.g., by "—". A temporarily locked feature will be grayed out, but the feature's value may still be displayed.

A hardware *Trigger* that can be switched *On* and *Off* is a typical example for making a feature **temporarily not available**. If switched *On*, an additional feature, the *TriggerPolarity,* becomes available and denotes whether the hardware signal should be interpreted as an *ActiveHigh* or an *ActiveLow* signal. If the *Trigger* is switched *Off*, the *TriggerPolarity* is meaningless and should be grayed out.

Figure 5 shows how this information is handled in the camera description file. The *Trigger* and the *TriggerPolarity* feature are implemented using nodes of the *Enumeration* type that map a set of enumeration entries to integer numbers. For example, the entries for the *Trigger* feature are *On*=1 and *Off*=0. The integer numbers are mapped to registers using nodes of the *IntReg* type.

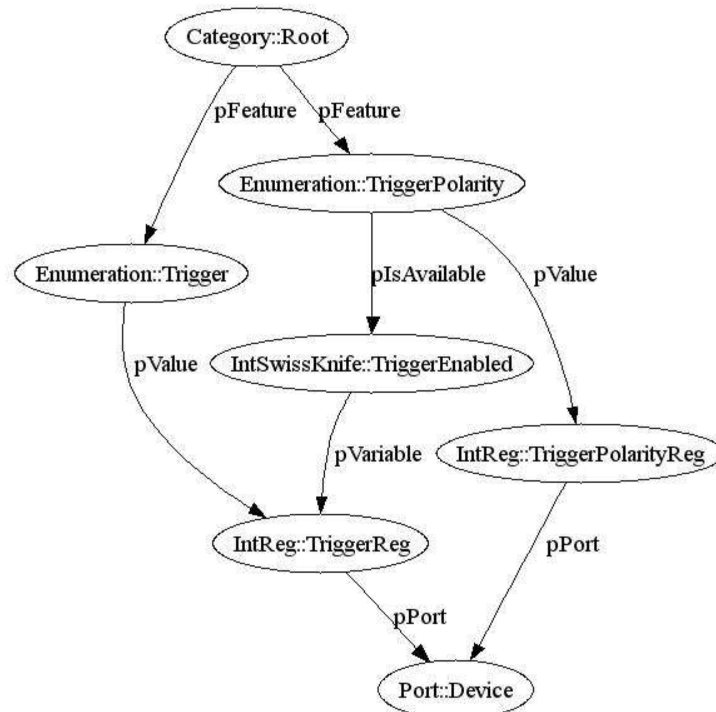


Figure 5 Controlling whether a feature is accessible

The *TriggerPolarity* node has a *pIsAvailable* link that needs to point to a node exposing an *IInteger* interface. If the value of this node is zero, the node is temporarily not accessible.[4]

In the example, *pIsAvailable* could directly point to *TriggerReg* because *Trigger=On* is mapped to 1 and *Trigger=Off* is mapped to 0. If this is not the case, a node of the *IntSwissKnife* type comes in handy. It computes an integer result from any number of other integer nodes using a mathematical formula. In the XML file, the node looks like this:

```
<IntSwissKnife Name="TriggerEnabled">
  <ToolTip>Determines if the Trigger feature is switched on</ToolTip>
  <pVariable Name="TRIGGER">TriggerReg</pVariable>
  <Formula>TRIGGER==1</Formula>
</IntSwissKnife>
```

The mathematical formula in the <*Formula*> entry is evaluated, yielding the result of the node. Before the evaluation, the symbolic names of the variables are replaced by the integer values of the corresponding nodes. In the example, there is only one <pVariable> entry pointing to the TriggerReg node and having the symbolic name TRIGGER. This is also found in the formula that reads “TRIGGER==1”.

So if the graphical user interface is updated, it will ask the *TriggerPolarity* node whether it is enabled. The *TriggerPolarity* node will in turn check the *IntSwissKnife*, which will in turn compute the outcome from the value of the *TriggerReg* node.

[4] This follows the C/C++ semantic for interpreting integers as Boolean values.

The *BytesPerPacket* feature of DCAM compliant 1394 cameras is a typical example for making a feature **temporarily locked**. The user can change this camera parameter, but only if the DMA of the PC adapter card is not yet set up for grabbing.[5] Setting up the DMA means that the transport layer asks the camera for the *BytesPerPacket* parameter and configures that value to the DMA. After this has been done, *BytesPerPacket* must not be changed until the transport layer releases the DMA. In the meantime, the parameter must be locked in the camera.

Note that the camera itself has no way of knowing whether the DMA is set up or not. As a consequence, the “normal” nodes in the camera description files cannot be used for controlling the lock status of *BytesPerPacket*.

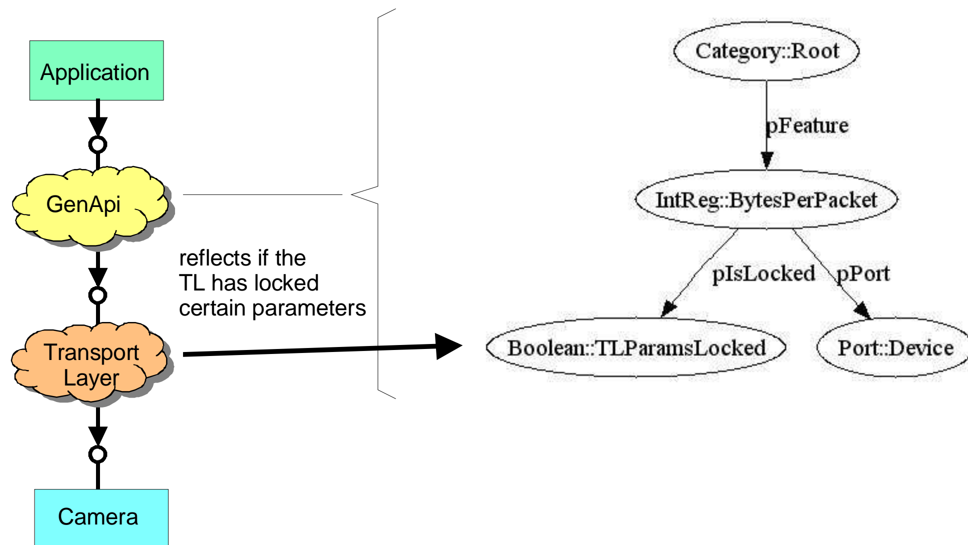


Figure 6 Locking a feature

The solution within GenApi is to provide a floating *Boolean* node *TLParamsLocked* (see Figure 6). The *BytesPerPacket* links to this node with a *pIsLocked* link. The transport layer (TL) needs to reflect its DMA status by updating the value of the *TLParamsLocked* node. Before it sets up the DMA, it locks the respective camera parameters (e.g., *BytesPerPacket*) by setting *TLParamsLocked* to true, and after the grab has been finished, it sets *TLParamsLocked* false again. Changing the *TLParamsLocked* node will in turn update the lock status of all dependent nodes, for example, the *BytesPerPacket* node.

Note that in order for this scheme to work generically, *TLParamsLocked* must be a standard node name and the transport layer must have access to the GenApi interface of the camera. In addition, the designer of the camera description file must be aware of which parameters will

[5] The reason is that the DMA of a OHCI compliant PC adapter card needs to know the *BytesPerPacket* parameter in advance of the data transfer to ensure that the frames are transferred to memory without causing CPU load.

be locked by the transport layer. This information is included in the transport layer standard, e.g., the DCAM specification, which specifies that during grab the number of packages per frame and the package size must be fixed.

A family of cameras where some members have a *Gamma* feature implemented and some do not is a typical example for a feature being **not implemented**. If the cameras have an **inquiry bit** advertising whether the camera has the *Gamma* feature implemented or not, you can maintain one camera description file for the whole family of cameras.

Figure 7 shows how to handle that case with GenICam. The *Gamma* feature node has a *pIsImplemented* link to a *GammaInq* node mapping to the inquiry bit in the camera. Multiple inquiry bits are typically packed into one register. For extracting the bits, the *MaskedIntReg* node type is used. It works like an *IntReg* node, but in addition, you can denote which bit or which contiguous group of bits you want to be extracted as an integer.

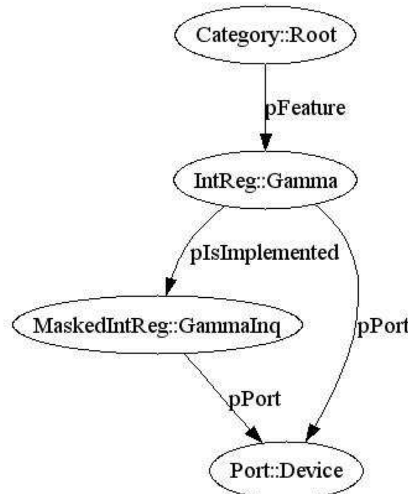


Figure 7 Checking whether a feature is implemented

2.6 Caching

If an implementation supports checking ranges, presence, and enable status for each write access, it would normally trigger a cascade of read accesses to the camera. However, most of the values required for validation do not change frequently or at all and can thus be cached. The camera description file contains all of the necessary means to ensure the cache's coherency.

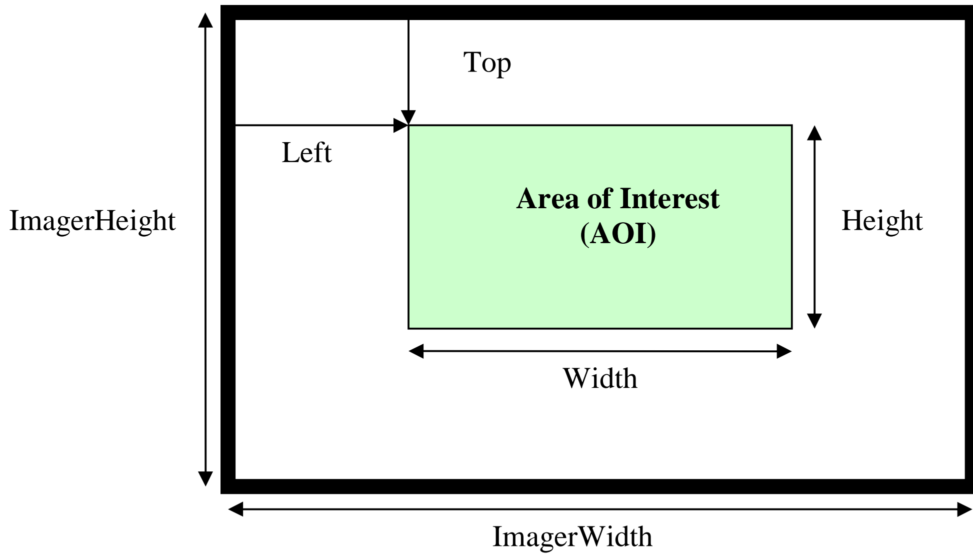


Figure 8 Area of Interest

To explain this, a more elaborate example must be used. Figure 8 shows an area of interest (AOI) on the imager in a camera. The camera will send only the data from within the AOI, which is given as a rectangle defined by the parameters *Top*, *Left*, *Width,* and *Height*.

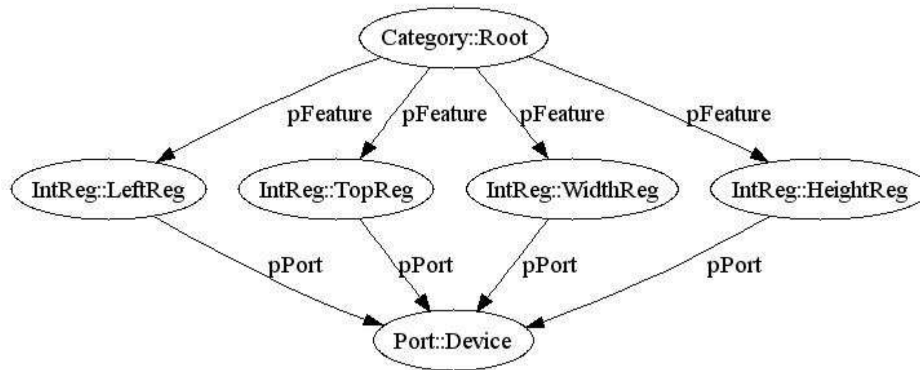


Figure 9 Controlling the Area of Interest

Each of these four parameters is exposed through a register as shown in Figure 9. This simple scheme, however, cannot deal with the fact that none of the four parameters has an unlimited range. Assuming that the pixel coordinates start with 0, the following restrictions apply:

$$0 \leq Left \leq ImagerWidth - Width$$

$$0 \leq Top \leq ImagerHeight - Height$$

$$1 \leq Width \leq ImagerWidth - Left$$

$$1 \leq Height \leq ImagerHeight - Top$$

To take these restrictions into account, the maximum values for each of the four parameters must be computed using *SwissKnife* nodes; the minimum values are fixed. The resulting GenApi node graph is shown in Figure 10. Note that a second layer of *Integer* nodes has been introduced and that the maximum values are taken from IntSwissKnife nodes.

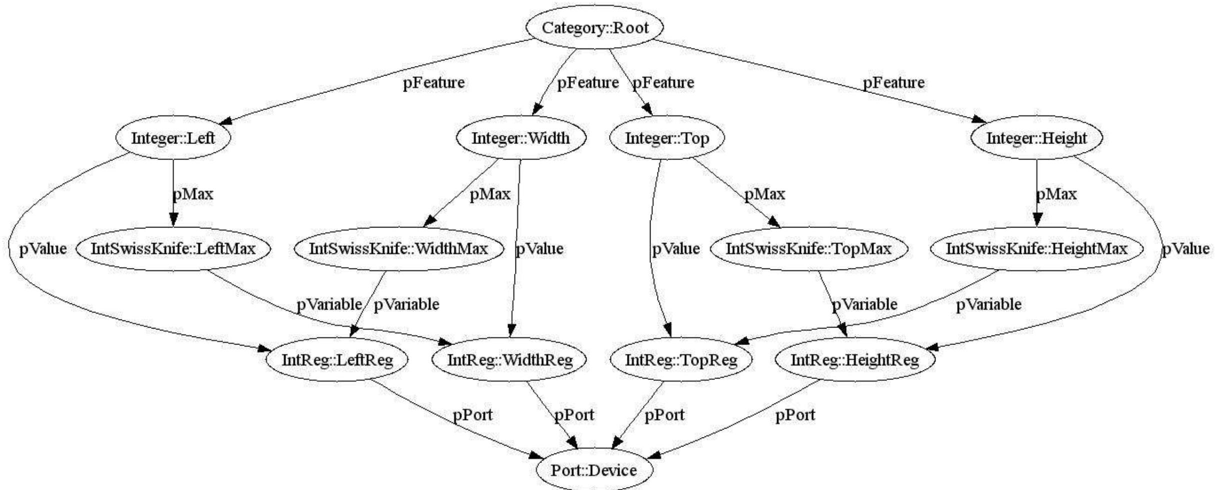


Figure 10 Controlling the Area of Interest while taking restrictions into account

Assuming an imager with VGA resolution (640x480), the XML code for the *TopMax* node might look like this:

```
<IntSwissKnife Name="TopMax">
  <pVariable Name="CURHEIGHT">HeightReg</pVariable>
  <Formula>480-CURHEIGHT</Formula>
</IntSwissKnife>
```

Returning to the topic of caching, you would not want the *HeightReg* to be read each time you set the *Left* feature, nor would you want the *TopMax* node to be evaluated each time. This is indeed not necessary if (and only if) you are certain that *HeightReg* will only change when the GenApi itself writes a new value to that register. If this is the case, you can cache the values of *HeightReg* and *TopMax*.

If the user writes a new value to *HeightReg*, the *HeightReg* cache can be updated immediately, and the *TopMax* cache needs to be invalidated. The next time someone accesses the *Left* node, it will read *TopMax*, thereby creating a new cache entry for *TopMax*.

As a rule, all clients of a node are informed if the node changes its content so that the clients can invalidate their caches.

Normally, the links between the nodes in the camera description file contain all of the information needed so that the implementation can deal with the caching without the user needing to worry about it. However, there are certain cases were the camera itself contains more dependencies than those directly described by the nodes.

Some cameras contain a feature called *Binning*. When *Binning* is switched on, the charge from adjacent pixels is merged together, yielding a larger full well at the cost of lower resolution. Assuming a VGA resolution imager, typical configurations are:

- No Binning (640 x 480)
- Horizontal Binning (320 x 480)
- Vertical Binning (640 x 240)
- Full Binning (320 x 240)

In GenICam, this feature would be described using an enumeration with the four entries given above (see Figure 11). However, changing the binning also means changing the imager size – not the real physical imager, but rather the logical imager size that imposes the restrictions on the AOI parameters.

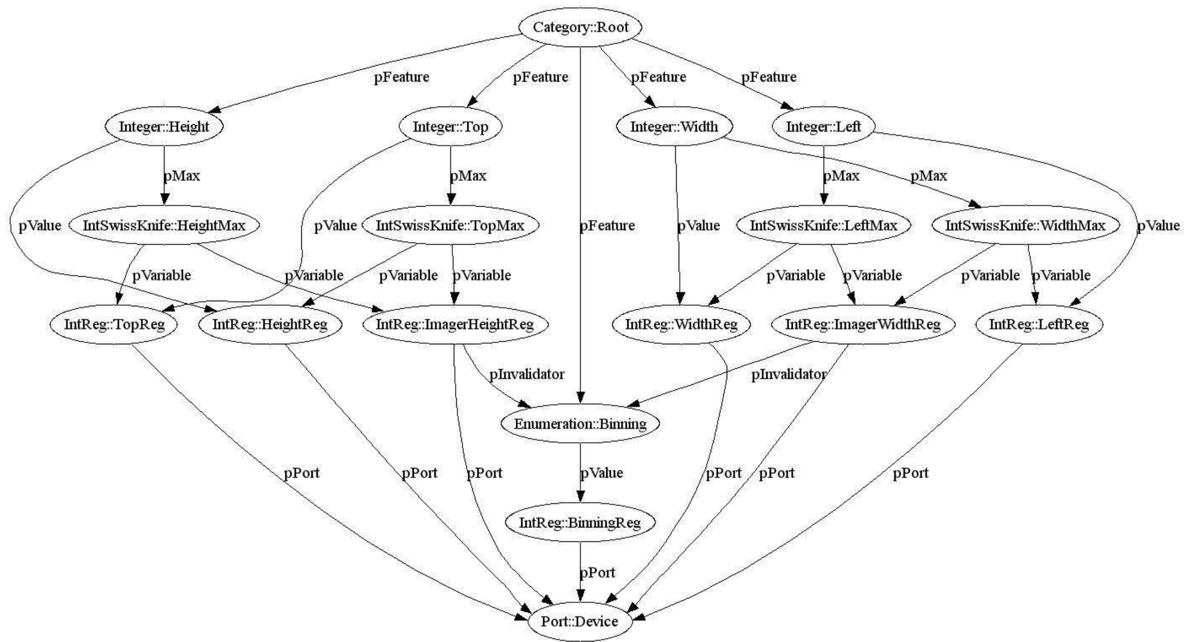


Figure 11 Controlling the Area of Interest taking binning into account

Let's assume that the camera provides the information about the current (logical) imager size with a register. As shown in Figure 11, this introduces two new nodes: *ImagerHeightReg* and *ImagerWidthReg*. The XML code for *TopMax* then looks like this:

```
<IntSwissKnife Name="TopMax">
   <pVariable Name="CURHEIGHT">HeightReg</pVariable>
   <pVariable Name="IMAGERHEIGHT">ImagerHeightReg</pVariable>
   <Formula>IMAGERHEIGHT-CURHEIGHT</Formula>
</IntSwissKnife>
```

As we have seen, the value of *ImagerHeightReg* will change if the user changes the *Binning* feature. However, there is no data flow between the two nodes. To make sure that the node

cache for *ImagerHeightReg* will be invalidated when the content of the *BinningReg* node changes, a *<pInvalidator>* link must be introduced between the two nodes. The sole purpose of this link is to document the hidden dependency between the two features and to make sure that the cache is always coherent.

2.7 Identifying and Versioning a Camera Description File

It must be possible to identify a camera description file, and thus the described camera, in a unique manner. In addition, a camera description file will typically evolve over time, e.g., when features are added to the corresponding camera product. This creates the necessity for a versioning mechanism. The GenApi syntax itself will also evolve over time, e.g., when new node types are added, thus a versioning mechanism for the schema is also required.

The necessary means are found in the attribute list of the *<RegisterDescription>* element, which is the outermost bracket of the XML file. Here is an example:

```
<RegisterDescription
  ModelName="Example01"
  VendorName="Test"
  ToolTip="Example 01 from the GenApi standard"
  StandardNameSpace="None"
  SchemaMajorVersion="1"
  SchemaMinorVersion="0"
  SchemaSubMinorVersion="1"
  MajorVersion="1"
  MinorVersion="0"
  SubMinorVersion="0"
  ProductGuid="1F3C6A72-7842-4edd-9130-E2E90A2058BA"
  VersionGuid="7645D2A1-A41E-4ac6-B486-1531FB7BECE6"
  xmlns="http://www.genicam.org/GenApi/Version_1_0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.genicam.org/GenApi/Version_1_0
../GenApiSchema_Version_1_0.xsd">
```

The camera described is identified by the *VendorName*: / *ModelName* pair. Assuming that vendor names are mutually exclusive due to trade marks, this scheme creates unique names. The *ToolTip* attribute is used to provide additional information about the device that can be displayed to the user, e.g., in a selection list of devices found on a bus.

Names inside a camera description file may come from different name spaces. This is described in more detail in section 2.8.1. Within a given camera description file, names come either from a custom name space or a standard name space. The attribute *StandardNameSpace* identifies the standard name space used in the file.

The versioning of the different items in a camera description file follows common rules, and a three part **version number** is used:

<Major>.<Minor>.<SubMinor>

An example would be ‘1.4.2’.

The following **compatibility rules** apply:

- Files with a higher Major version number are not backward compatible

- Files with a higher Minor version number are backward compatible
- Changes in the SubMinor version number are bug fixes only; always use the file with the highest available SubMinor version number

Example: Version 1.3.0 is compatible with version 1.1.*, 1.2.* and 1.3.* (were * means *don't care*). It is not compatible with version 2.*.*. If version 1.3.2 is available, it should be used instead of 1.3.0.

2.7.1 Versioning the Schema

The attributes *SchemaMajorVersion*, *SchemaMinorVersion*, and *SchemaSubMinorVersion* describe the version of the GenApi schema used for the XML file. These attributes are mandatory. They are for information purposes. In addition, the Major and Minor schema version numbers are encoded in the namespace (see *xmlns* entry) and the schema's file name (see *xsi:schemaLocation* entry).

In the example, the namespace reads "http://www.genicam.org/GenApi/Version_1_0". A program seeking the schema file might either retrieve it over the internet using the URL or look at the file path given optionally in the second part of the *schemaLocation*. In the example, the path reads "../../GenApi/GenApiSchema_Version_1_0.xsd" and assumes that the XML file is stored within the folder structure of the GenICam reference implementation.

The *xmlns:xsi* entry "http://www.w3.org/2001/XMLSchema-instance" describes the namespace of the schema language itself.

Note that an implementation supporting, e.g., schemas up to version 1.3.* must have three schema files present: for versions 1.0.*, 1.2.*, and 1.3.*. This is required for backward compatibility – since older XML files come with an older namespace, they need older schema files. On the other hand, an XML file using a later schema version not yet supported by the implementation, say 1.4.*, needs to be rejected, hence the necessity to have the version number coded in the schema's namespace.

2.7.2 Versioning the Camera Description File

The *MajorVersion*, *MinorVersion*, and *SubMinorVersion* attributes describe the version of XML file itself. The camera vendor is responsible for following the compatibility rules.

What does backward compatibility mean with respect to camera description files? Assume a camera that in version 1.0 has only a single feature implemented. Now assume the camera's firmware is extended to have another feature. There are two ways to deal with this situation in the camera description file. If the feature is just added to the XML file, this implicitly states that the feature is always there. Because this is not true with older cameras, the new file will not be backward compatible, and consequently it must get the version number 2.0.

A second, smarter way to deal with the situation is to introduce an inquiry register in the camera(!) where the user can check to see if the new feature is present or not. The new feature can now be added in a way that lets the user learn from the access mode of the feature whether the feature is present or not. This makes the new file backward compatible and its version number would be 1.1. Of course, this is possible only if an inquiry mechanism has been implemented in the camera from the beginning. The benefit of using the second method is that only one camera description file must be maintained for a whole family of cameras.

Note that **compatibility** refers only to the **feature nodes** and their behavior, not to **implementation nodes** (for details see section 2.8.2).

2.7.3 Identifying and Caching the Camera Description File

Loading a camera description file may involve one or more pre-processing steps. To speed things up, the pre-processed XML file can be cached. For caching, a key is required that uniquely identifies the camera description file. A combination of the *<RegisterDescription>* element's *VendorName, ModelName*, *MajorVersion*, *MinorVersion*, and *SubMinorVersion* attributes would be sufficient, but is a bit clumsy to use.

To simplify this caching, the *VersionGuid* attribute has been introduced. The *VersionGuid* attribute holds a global unique identifier (GUID) that must be changed each time one of the *VendorName, ModelName*, *MajorVersion*, *MinorVersion*, or *SubMinorVersion* attributes changes. The *VersionGuid* uniquely identifies a certain version of a camera description file, hence the name.

Instead of caching all of the different camera description files that might come along in different versions over time, it can make sense to cache only the most recent file, which contains all others via backward compatibility. There is one such file per *VendorName, ModelName,* and *MajorVersion* number. The caching key for that kind of file is the *ProductGuid,* which also holds a global unique identifier (GUID) and which must be changed each time the *VendorName, ModelName,* or the *MajorVersion* changes.

2.8 Available Node Types

This section gives a brief description of each available node type, of their behavior, usage, and most interesting parameters. In addition, there is a formal description for the XML layout of each node in an XML schema file included with the GenICam standard. This schema file can be read by most XML editors and will greatly simplify creating camera description files by providing a syntax check and context sensitive fill-in helpers.

This document refers to the **GenApi schema version 1.0** found in the file *GenApiSchema_Version_1_0.xsd.* Note that in subsequent versions of the standard, additional node types, elements, and attributes may be added, however, backward compatibility will be maintained if at all possible.

2.8.1 Node

The *Node* type contains those elements and attributes common to all other node types. A stand-alone *Node* node is pretty useless, but is possible for testing purposes. Here is an example:

```
<Node Name="Gain" NameSpace="Standard">
<Extension>
  <MyElement>Something vendor specific</MyElement>
</Extension>
<ToolTip>The amplitication of the camera</ToolTip>
<Description>A more elborated description</Description>
<DisplayName>Gain</DisplayName>
<Visibility>Expert</Visibility>
<EventID>12fc</EventID>
<pIsImplemented>SomeNode1</pIsImplemented>
<pIsAvailable>SomeNode2</pIsAvailable>
<pIsLocked>SomeNode3</pIsLocked>
<ImposedAccessMode>RO</ImposedAccessMode>
<pAlias>SomeNode4</pAlias>
```

Each node has a *Name* attribute. The *Name* must be **unique** within the camera description file. Names can be composed of alphanumeric characters [A-Z a-z 0-9]. The schema also allows the use of the underscore '_', but the underscore should not be used by camera description files designers because the reference implementation uses it for automatically generated names.

Each *Name* lives inside a **name space**. The name space is identified by the combination of the *NameSpace* attribute of the node and the *StandardNameSpace* attribute of the enclosing *<RegisterDescription>* element (see section 2.7). The *NameSpace* attribute can have two possible values: *Custom* or *Standard*. If it is *Custom,* any name can be used as long as it is unique within the camera description file. If it is *Standard,* it must come from one of the **standard feature name lists** available for the following camera types (for more details see section 2.9):

- *IIDC* : cameras following the **1394 IIDC** standard (also called **DCAM** standard)
- *GEV* : cameras following the **GigE Vision** standard
- *CL* : cameras following the **Camera Link** standard
- *None* : no standard is used

An *<Extension>* element can be used to add custom specific data to a camera description file. All elements placed inside the <Extension> element are ignored.

The *<ToolTip>* element gives a short description of the node. It may also be used as a brief description for a reference documentation automatically generated from the camera description file.

The *<Description>* element gives a more detailed description of the node. It may also be used as a long description for a reference documentation automatically generated from the camera description file.

The *<DisplayName>* element lets you define feature captions that might be used instead of the feature's *Name*.

The *<Visibility>* element defines the user level that should get access to the feature. Possible values are: *Beginner*, *Expert*, *Guru*, and *Invisible*. The latter is required to make a feature show up in the API, but not in the GUI (see section 2.8.2).

The <*EventID*> element is used for delivering asynchronous events. A camera might send an event package to indicate that one ore more data item in the camera has changed its value. GenICam handles the event by invalidating the nodes corresponding to the data items. The nodes are found by the EventID which is a hexadecimal number which comes with the event package from the camera. Each node can have one (optional) EventID element.

The <p*IsImplemented*>, <p*IsAvaliable*>, and <p*IsLocked*> elements contains the names of nodes implementing an IInteger interface. If these elements are present, they influence the access mode of this node as described in section 2.5.

An <*ImposedAccessMode*> element can be used to narrow the access mode resulting from other nodes.

<*pAlias*> points to another node which describes the same feature in a different manner. This feature will be mainly used in a GUI: a Category might be replaces by its alias if not all members are shown; an integer and a flat note might be aliases of each other if they show the raw and the abs value of a feature.

2.8.2 Category

The *Category* node is used to group features that should be presented to the user. It implements the *ICategory* interface and inherits all *Node* elements. It also contains a list of <*pFeature*> elements that point to the features contained in the category. Categories can contain other categories, thus forming a tree of arbitrary depth.

There is one special *Category* node with the standard name *Root*[6] that is the basis of the category tree. Users may want to start browsing the features of a camera from here. The following example creates the node graph shown in Figure 12:

[6] The feature *ICategory::Root* is defined in all standard name spaces.

```
<Category Name="Root" NameSpace="Standard" >
  <pFeature>ScalarFeatures</pFeature>
  <pFeature>Trigger</pFeature>
</Category>

<Category Name="ScalarFeatures" >
  <pFeature>Shutter</pFeature>
  <pFeature>Gain</pFeature>
  <pFeature>Offset</pFeature>
  <pFeature>WhiteBalance</pFeature>
</Category>

<Category Name="WhiteBalance" >
  <pFeature>RedGain</pFeature>
  <pFeature>BlueGain</pFeature>
</Category>

<Category Name="Trigger" >
  <pFeature>TriggerMode</pFeature>
  <pFeature>TriggerPolarity</pFeature>
</Category>
```

Note that a user accessing the nodes by browsing the **category tree** is intended only to see **features nodes** in the first layer below the *Category* nodes. Nodes deeper in the graph are called **implementation nodes** and are retrievable only by name or in a special browse mode that the implementation might provide for debugging purposes. Note that the names and the layout of the implementation nodes may change without notice in a new release of a camera description file, even if the vendor declares it backward compatible (see also section 2.7.3).

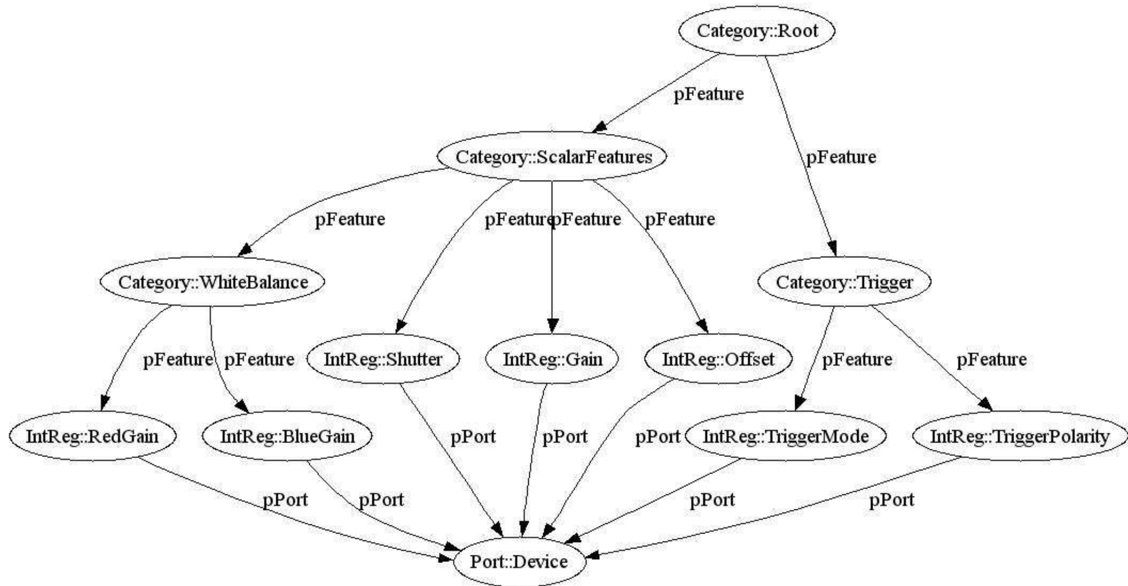


Figure 12 A tree of categories

2.8.3 Register

The *Register* node maps to a contiguous array of bytes in the register space of the camera. The *Register* node implements the *IRegister* interface and inherits its elements and attributes from the *Node* node. It in turn leaves its elements and nodes to all specialized register access nodes, such as *IntReg*, *StringReg,* etc. A *Register* node, however, can also be instantiated on its own giving access to the raw binary data. Here is a simple example:

```
<Register Name="SensorTemperature">
  <Address>0xff00</Address>
  <Length>4</Length>
  <AccessMode>RO</AccessMode>
  <pPort>Device</pPort>
  <Cachable>No</Cachable>
  <PollingTime>10000</PollingTime>
</Register>
```

The example exposes the temperature of the camera's sensor. The temperature can change at any time and is therefore not cacheable. If displayed, it should be polled every 10.000 ms.

The *<Address>* element gives the address of the register in the camera's register space.

The *<Length>* element gives the length of the register in bytes.

The *<AccessMode>* element can have the values RW (read/write), RO (read only), or WO (write only) and indicates what the camera can deliver.

The *<pPort>* element contains the name of a Port node that gives access to the camera's register space (for details see section 2.8.15).

The *<Cacheable>* element can have the values *No*, *WriteThrough*, and *WriteAround*. *WriteThrough* means that a value written to the camera is written to the cache as well. *WriteAround* means that only read values are written to the cache. The latter behavior makes sense, for example, with an *IFloat::Gain* node where the user can write any value, but when reading back, will retrieve a value that has been rounded by the camera to a value the internal analog-to-digital converter is able to deliver. Note that caching is an optional feature of any implementation.

The *<PollingTime>* element denotes the recommended polling time interval [in ms] for reading a feature that is not cacheable. Note that polling is an optional feature of any implementation and the polling time is a hint only.

Instead of a single *<Address>* entry, a register can have multiple entries for the *<Address>*, *<pAddress>*, and/or *<IntSwissKnife>* types. The values of these entries are summed, yielding the address of the register node.

The *<pAddress>* element points to a node implementing an IInteger interface delivering a contribution to the final address.

The *<IntSwissKnife>* element can be used to compute an address contribution from multiple sources (for details see section 2.8.12).

The *<pIndex Offset="12">* element points to a node implementing an IInteger interface delivering an *index*. The element has an attribute *Offset*. The product of index and Offset is added to the address.

The <p*Invalidator*> element contains the name of a node that when changed, will invalidate the content of this node as described in section 2.6.

The following example shows how to use this mechanism for indirect addressing (see also Figure 13):

```
<Integer Name="BaseAddress">
  <Value>0xff00</Value>
</Integer>

<IntReg Name="Gain">
  <Address>0x04</Address>
  <pAddress>BaseAddress</pAddress>
  <Length>4</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <Sign>Unsigned</Sign>
  <Endianess>LittleEndian</Endianess>
</IntReg>

<IntReg Name="Offset">
  <Address>0x08</Address>
  <pAddress>BaseAddress</pAddress>
  <Length>4</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <Sign>Unsigned</Sign>
  <Endianess>LittleEndian</Endianess>
</IntReg>
```

This example mimics a C/C++ struct of the form:

```
struct {                // BaseAddress 0xff00
  uint32_t Reserved;
  uint32_t Gain;        // Offset 0x04
  uint32_t Offset;      // Offset 0x08
};
```

The value for the struct’s base address comes from a *BaseAddress* constant integer node and is fed into the node using a <*pAddress*> element. Each element of the (*Gain* and *Offset*) struct has an offset that is added to the base address using an <*Address*> element.

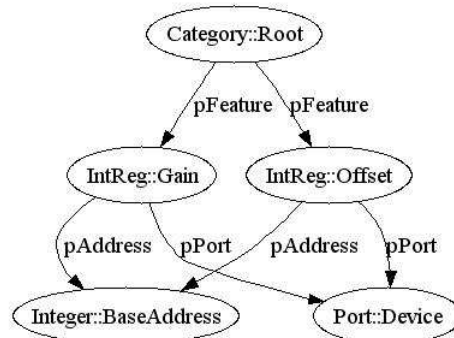


Figure 13 Indirect addressing: mapping a C/C++ struct

Note that this mechanism is used very frequently with 1394 DCAM compliant cameras where the whole standard register block has a common base address that must be parsed from a IEEE 1212 configuration ROM structure at run-time (see also the *ConfRom* node type).

2.8.4 Arrays and Selectors

Indirect addressing as described in the previous chapter is also used for accessing arrays. The following example shows how this is done (see also Figure 14):

```
<Integer Name="LUTIndex">
  <Value>0</Value>
  <Min>0</Min>
  <Max>255</Max>
  <pSelected>LUTEntry</pSelected>
</Integer>

<IntReg Name="LUTEntry">
  <IntSwissKnife Name="LUTEntryAddress">
    <pVariable Name="INDEX">LUTIndex</pVariable>
    <Formula>0xff00 + INDEX * 4</Formula>
  </IntSwissKnife>
  <Length>4</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <Sign>Unsigned</Sign>
  <Endianess>LittleEndian</Endianess>
</IntReg>
```

A LUT Entry element is used as a pointer into the LUT. The address of this element is computed using an embedded *<IntSwissKnife>* element that computes the address of the *LUTEntry* element according to the formula: $BaseAddress + LUTIndex \cdot \text{sizeof}(LUTEntry)$. The *LUTIndex* is a “floating” *Integer* node that is not connected to the camera. Instead, it starts with *<Value>* and can be changed between *<Min>* and *<Max>* by the user.

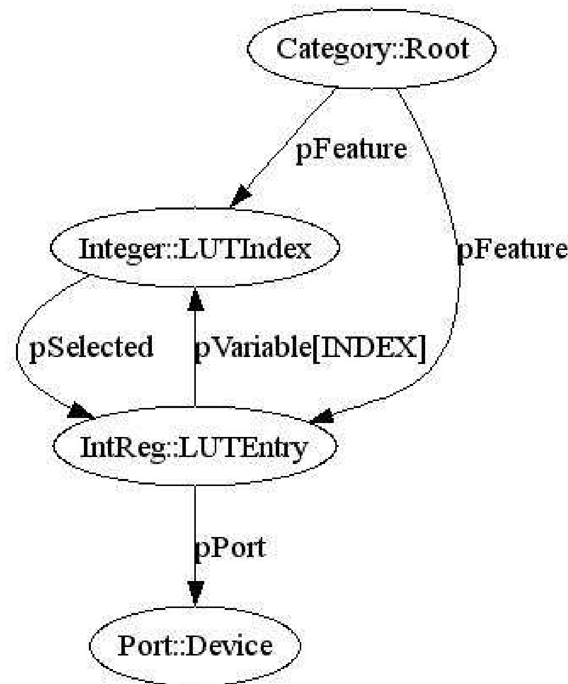


Figure 14 Accessing a LUT array

The fact that the LUTIndex can be used to select a specific LUTEntry is made explicit by the <*pSelected*> element in the LUTIndex node. Nodes implementing an *IInteger* or and *IEnumeration* interface can have any number of *pSelected* entries to indicate that the **selected nodes** will show a different value depending on the value of **selector node**. Information whether a node is a selector and which are the selected nodes can be retrieved using the *ISelector* interface which has the according methods *IsSelector* and *GetSelectedFeatures*. Using this interface a GUI can for example show a list of LUTEntries because it knows that if it runs LUTIndex (selector) from min to max it will retrieve an array of different values from LUTEntry (selected).

Note that the selector and the indirect addressing scheme can also be used to access **multi-dimensional arrays** via multiple indices.

2.8.5 Integer, IntReg, MaskedIntReg

The *IInteger* interface provides access to signed 64 bit integer variables that have a *Value* restricted by the *Minimum*, *Maximum*, and *Increment* parameters according to the formulas:

$$Value = Minimum + i \cdot Increment \quad \text{with} \quad 0 \le i \le \frac{Maximum - Minimum}{Increment}$$

The IntReg node maps to byte-aligned integer registers. It inherits the elements and attributes from *Register* nodes. Below is an example mapping to a 2 byte unsigned integer. Note that such a variable has the following restriction parameters: *Minimum* = 0, *Maximum* = 65.535, *Increment* = 1.

```
<IntReg Name="Gain">
  <Address>0x1234</Address>
  <Length>2</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <Sign>Unsigned</Sign>
  <Endianess>BigEndian</Endianess>
</IntReg>
```

The *<Sign>* element can have the value *Singed* or *Unsigned*. Note that unsigned int64 values are not available.

The *<Endianess>* element can have the values *LittleEndian* or *BigEndian* and refers to the endianess of the device as seen trough the transport layer. The transport layer must attempt to not change the endianess. Note that the implementation must be aware of whether it is running itself on a little-endian or big-endian machine.

Sometimes integers are not byte aligned, but are packed into a register. In this case, a *MaskedIntReg* is used. It inherits the elements and attributes from the *Register* node. The following XML code is an example for a 12 bit integer packed into a 2 byte register. The *<LSB>* and *<MSB>* elements denote the least significant bit and the most significant bit respectively.

```
<MaskedIntReg Name="Offset">
  <Address>0x2345</Address>
  <Length>2</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <LSB>11</LSB>
  <MSB>0</MSB>
  <Sign>Unsigned</Sign>
  <Endianess>BigEndian</Endianess>
</MaskedIntReg>
```

In the case where only a single bit must be mapped – which is quite common for presence inquiry bits – instead of using an *<LSB>* and an *<MSB>* element with the same value, you can also use a *<Bit>* entry.

```
<MaskedIntReg Name="OffsetInq">
  <Address>0x2345</Address>
  <Length>2</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <Bit>15</Bit>
  <Sign>Unsigned</Sign>
  <Endianess>BigEndian</Endianess>
</MaskedIntReg>
```

The numbering of the bits differs between big-endian and little-endian as is shown for a 32 bit integer below:

```
Little-Endian:      MSB   ...   LSB
                     31   ...    0

Big-Endian:         MSB   ...   LSB
```

```
0    ...     31
```

The LSB is the bit which maps to the 2^0 digit. Note that with big-endian the equation MSB ≤ LSB holds true while with little-endian the opposite holds true: LSB ≤ MSB.

The *Integer* node type is used to merge the *Value* and the *Minimum*, *Maximum*, and *Increment* parameters from different sources. It inherits the elements and attributes from the *Node* node. The restriction parameters are either given as constants using the *<Min>*, *<Max>*, and *<Inc>* elements or as a pointer to other IInteger nodes using the *<pMin>*, *<pMax>*, and *<pInc>* elements.

The Value normally comes from another node using the *<pValue>* element. Alternatively, a constant can be given inside a *<Value>* element. In this case, the node is a “floating” variable that can be set by the user to any value allowed by the restriction parameters. The given constant is the start value. A typical example is the following *Index* node that can be set to the values 0, 2, 4, …, 254:

```
<Integer Name="Index">
  <Value>0</Value>
  <Min>0</Min>
  <Max>255</Max>
  <Inc>2</Inc>
</Integer>
```

The *<Representation>* element gives a hint about how to display the integer. If the element is *Linear* or *Logarithmic,* a slider with the appropriate behavior should be implemented. If the element is *Boolean,* a checkbox should be used. *PureNumber* means to use an edit box only with decimal display; *HexNumber* means the same with hexadecimal display.

Integer, *IntReg* and *MaskedInt* nodes can also have an *<pSelected>* element. For a descripton see section 2.8.4.

2.8.6 StructReg

MaskedInt node are often used to pick a filed of bits from a register. If a complete *MaskedInt* entry is used for each bit there is a lot of unnecessarily copied data in the camera description file because the different *MaskedInt* entries share most of their elements like, e.g. the *<pPort>* element, the *<Endianess>* etc.

In order to overcome this the *StructReg* node has been introduced. Here an example:

```
<StructReg Comment="VFormat7InqReg">
  <ToolTip>Inquiry register for video format 7 color codes</ToolTip>
  <Address>0x14</Address>
  <pAddress>VFormat7ModeCsrBase</pAddress>
  <Length>4</Length>
  <AccessMode>RO</AccessMode>
  <pPort>Device</pPort>
  <Endianess>BigEndian</Endianess>
  <StructEntry Name="VFormat7Mono8InqReg">
    <ToolTip>Inquiry for ColorCode Mono8</ToolTip>
    <Bit>31</Bit>
  </StructEntry>
  <StructEntry Name="VFormat7YUV422InqReg">
    <ToolTip>Inquiry for ColorCode YUV8 422</ToolTip>
```

```
      <Bit>29</Bit>
    </StructEntry>
    </StructEntry>
    <StructEntry Name="VFormat7Raw8InqReg">
      <Bit>24</Bit>
    </StructEntry>
  </StructReg>
```

The *StructReg* node contains the same elements as the *MaskedInt* element. In addition it contains one or more <*StructEntry*> elements which in turn can contain again the same elements as the *MaskedInt* element. A pre-processor replaces the *StructReg* node with a set of *MaskedInt* nodes: From each <*StructEntry*> element one *MaskedInt* node is created which gets the *Name* attribute from the *StructEntry* element, all its sub-elements, plus all elements from the *StructReg* node which are not present already in the <*StructEntry*> element. Thus the first MaskedInt node created from the example above would look like this.

```
  <MaskedInt Name="VFormat7Mono8InqReg ">
    <Address>0x14</Address>
    <pAddress>VFormat7ModeCsrBase</pAddress>
    <Length>4</Length>
    <AccessMode>RO</AccessMode>
    <pPort>Device</pPort>
    <Endianess>BigEndian</Endianess>
    <ToolTip>Inquiry for ColorCode Mono8</ToolTip>
    <Bit>31</Bit>
  </MaskedInt>
```

Note that the <*ToolTip*> element was selected from the <*StructEntry*> element, not from the <*StructReg*> node. In contrast the entry with the Name *VFormat7Raw8InqReg* would inherit the <*ToolTip*> element from the <*StructReg*> node because it has no own. The <*StructReg*> element has an *Comment* attribute which describes it.

2.8.7 Boolean

The *Boolean* node maps the integer value in the <*OnValue*> element to true and the integer value in the <*OffValue*> element to false. The *Boolean* node implements the *IBoolean* interface and inherits the elements and attributes from the *Node* node. The following example shows how to use this capacity for a Trigger node that can be displayed in a GUI as a check box:

```
<Boolean Name="Trigger">
  <pValue>TriggerReg</pValue>
  <OnValue>1</OnValue>
  <OffValue>0</OffValue>
</Boolean>

<IntReg Name="TriggerReg">
  <Address>0x6789</Address>
  <Length>1</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <Sign>Unsigned</Sign>
  <Endianess>BigEndian</Endianess>
</IntReg>
```

2.8.8 Command

The *ICommand* interface lets the user submit a command by calling the method *Execute* and then poll to learn if the execution has been accomplished by calling the method IsDone.

The corresponding *Command* node inherits the elements and attributes of the *Node* node.

In addition it has a *CommandValue* element which holds an integer constant which is written into a node which is referenced to by a *pValue* element. Writing the command value submits the command. *IsDone* reads the value back and returns false as long as return value equals the command value. In order to make a floating *Command* node possible instead of a *pValue* element also a *Value* element is allowed. The CommandValue can alternatively also be taken from *pCommandValue*. A *<PollingTime>* entry is provided in order to handle for self clearing commands.

2.8.9 Float, FloatReg

The *IFloat* interface has a definition similar to the definition of the *IInteger* interface as described in the section above. It has a *Value* that is restricted by the *Minimum* and *Maximum* parameters, but in contrast to integer, there is no increment. In addition, *IFloat* exposes a *Unit* that is just a string for display purposes.

The *Float* node is built analogously to the *Integer* node in that it has the *<Value>, <Min>*, *<Max>* or <p*Value>, <pMin>*, *<pMax>* restriction parameters respectively. In addition, it can have a *<Representation>* element that can take the values *Linear* and *Logarithmic* plus a *<Unit>* element that contains the unit as a string. Here an example:

```
<Float Name="Exposure">
  <pValue>ExposureReg</pValue>
  <Min>0.02</Min>
  <Max>10.0</Max>
  <Unit>ms</Unit>
</Float>
```

A *FloatReg* node can be used to extract a floating point value from a byte aligned register. The *FloatReg* node inherits the elements and nodes of the *Register* node. It also has an *<Endianess>* element. The *Length* can be either 4 bytes (single precision float) or 8 bytes (double precision float). The number format has to be according to IEEE standard 754-1985.

2.8.10 Enumeration, EnumEntry

The *Enumeration* node maps a **name** to an **index value** and implements the *IEnumeration* interface. The *Enumeration* node holds a list of *EnumEntries* with each representing a possible {name, index} pair. The *Enumeration* node inherits the elements and attributes of the *Node* node. In addition, it has either a <*Value*> element that represents the current index value or a <*pValue*> element that connects to a node with an *IInteger* interface.

The following example shows an *Enumeration* describing the camera's *ColorCode*. If the *ColorCodeReg* is set to 1, for example, the camera is configured to *Mono16*.

```
<Enumeration Name="ColorCode">
  <EnumEntry Name="Mono8">
    <Value>0</Value>
  </EnumEntry>
  <EnumEntry Name="Mono16">
    <Value>1</Value>
  </EnumEntry>
  <EnumEntry Name="YUV422">
    <Value>3</Value>
  </EnumEntry>
  <pValue>ColorCodeReg</pValue>
</Enumeration>

<IntReg Name="ColorCodeReg">
  <Address>0x1234</Address>
  <Length>1</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
  <Sign>Unsigned</Sign>
  <Endianess>BigEndian</Endianess>
</IntReg>
```

Quite often, some of the EnumEntries in the list are temporarily unavailable and thus should not be presented to the user. To describe this with GenICam, you can have <*pIsImplemented*> and <*pIsAvailable*> elements in the *EnumEntry* sub-nodes, just as you can have with any other node.

Typically, the implementation will pre-process the camera description file and will create a separate node with the *Name* "EnumerationName_EnumEntryName" for each *EnumEntry*. Instead of the *EnumEntry* itself, a <*pEnumEntry*> element is placed in the *Enumeration* node. The original name of the *EnumEntry* is copied to the <*Symbolic*> element inside the newly created *EnumEntry* node. The index value represented by the EnumEntry is copied to the *EnumEntry*'s <*Value*> element.

Enumeration nodes can also have an <*pSelected*> element. For a descripton see section 2.8.4.

2.8.11 StringReg

A string is a (possibly null-terminated) ASCII string placed somewhere in the address space of the camera. A string is exposed via an *IString* interface. The example below shows how to extract the model name of the camera using a *StringReg* node. We assume that the *ModelName* can have a maximum of 128 bytes including the terminating null character.

```
<StringReg Name="ModelName">
  <Address>0x1234</Address>
  <Length>128</Length>
  <AccessMode>RO</AccessMode>
  <pPort>Device</pPort>
</StringReg>
```

You can get and set a string through the *IString* interface.

2.8.12 SwissKnife, IntSwissKnife, Converter, and IntConverter

To do mathematical computations within GenICam, the *SwissKnife* node dealing with float numbers and the *IntSwissKnife* node dealing with integers have been introduced. Both have the same syntax.

The following example shows how the product of two numbers is computed. The *XTimesY* node exposes an *IInteger* interface reading 504 (=12*42):

```
<IntSwissKnife Name="XTimesY">
  <pVariable Name="X">XValue</pVariable>
  <pVariable Name="Y">YValue</pVariable>
  <Formula>X*Y</Formula>
</IntSwissKnife>

<Integer Name="XValue">
  <Value>42</Value>
</Integer>

<Integer Name="YValue">
  <Value>12</Value>
</Integer>
```

The *<Formula>* element contains a mathematical formula that can refer to variables defined by *<pVariable>* elements which point to an IInteger node and have a *Name* attribute that defines the name of the variable inside the formula. The variable name must be upper case.

The Swiss knife used in the reference implementation is quite powerful. However, to simplify the task for people wanting to do their own implementation, the standard only allows a restricted set of mathematical operations. The following operations are supported by the standard:

( )	brackets
+ - * /	addition, subtraction, multiplication, division
%	remainder
**	power
& | ^ ~	bitwise and / or / xor / not
<> = > < <= >=	logical relations not equal / equal / greater / less / less of equal / greater or equal

&& ||	logical and / or
<< >>	shift left, shift right

Conditional operator:

<condition> ? <true expr.> : <false expr.>

Functions:

SGN, NEG,

Functions present only with the SwissKnife but not with the IntSwissKnife:

ATAN, COS, SIN, TAN, ABS, EXP, LN, LG, SQRT,

TRUNC, FLOOR, CEIL, ROUND(x, precision),

ASIN, ACOS, SGN, NEG, E, PI

When embedding formulas in XML files the problem arises that the characters <, >, and & cannot be used directly because they are part of the XML syntax. There are two possible solutions for that problem.

First you can escape these letters as follows:

<	becomes	*<*	(lt = thess than)
>	becomes	*>*	(gt = greater than)
&	becomes	*&*	(amp = ampersand)

As a result the formula `(x>0) && (x<10)` becomes

```
<formula>(x &gt; 0) &amp;&amp; (x &lt; 10)</formula>
```

Alternatively you can declare the whole formula as non-XML-text by bracketing it with `<![CDATA[` and `]]>`. The formula then becomes:

```
<formula><![CDATA[ (x>0) && (x<10) ]]>/formula>
```

While the interface of the *SwissKnife* is read only the *Converter* works bi-directionally. It implements an *IFloat* interface, looks a bit like the *SwissKnife* but contains an additional *<pValue>* element which can point to an *IInteger* or *IFloat* interface. It has two formulas: the *<FormulaFrom>* describes how to make the float from the int and the *<FormulaTo>* describes how to make the int from the float. The *<Slope>* entry indicates if the formula is monotonously *Increasing* or *Decreasing*, if it is *Varying* (in this case the full number range is used), or if the slope is determined in an *Automatic* way by probing the function.

The following example shows a Converter which computes an absolute shutter value (a float) by multiplying a raw shutter value (an integer) with a time base (another integer).

```
<Converter Name="ShutterAbs">
  <pVariable Name="TIMEBASE">TimeBase</pVariable>
  <FormulaTo> FROM / TIMEBASE </FormulaTo>
  <FormulaFrom> TO * TIMEBASE </FormulaFrom>
  <pValue>ShutterRaw</pValue>
  <Slope>Increasing</Slope>
</Converter>

<Integer Name="ShutterRaw">
  <Value>2</Value>
</Integer>

<Integer Name="TimeBase">
  <Value>10</Value>
</Integer>
```

The *IntConverter* works like the Converter but implements an *IInteger* interface.

2.8.13 ConfRom, TextDesc, and IntKey

The **DCAM** standard for 1394 cameras implements a Configuration ROM that is a tree-like data structure defined in the **IEEE 1212 standard**. Its main purpose in the context of a camera is to expose the model name, vendor name, the supported interface standard version, and the base address for the DCAM standard register block. Due to the special layout of an IEEE 1212 compliant Configuration ROM, a special *ConfROM* node has been introduced to give access to all of this information.

The following example searches for a unit directory with the unit ID given in the *<Unit>* element that describes a DCAM compliant camera. Inside this unit directory, three entries are picked and made available as sub-nodes. The *<IntKey> CommandRegBase* element will transform to a node with the *IInteger* interface reading the base address for the DCAM registers. The *<TextDesc> VendorName* and *ModelName* elements transform to nodes with the *IString* interface reading the vendor and the model name of the camera.[7] The hex numbers in the elements are the respective **key values** that the entries are stored with in the unit directory.

[7] Note that the strings inside the Configuration ROM are not required to be null-terminated; see IEEE 1212.

```
<Category Name="Root">
  <pFeature>CommandRegBase</pFeature>
  <pFeature>VendorName</pFeature>
  <pFeature>ModelName</pFeature>
</Category>

<ConfRom Name="ConfRom">
  <Unit>0x00A02D</Unit>
  <Address>0x400</Address>
  <pAddress>InitialNodeSpace</pAddress>
  <Length>0x400</Length>
  <pPort>Device</pPort>
  <IntKey Name="CommandRegBase">0x40</IntKey>
  <TextDesc Name="VendorName">0x81</TextDesc>
  <TextDesc Name="ModelName">0x82</TextDesc>
</ConfRom>

<Integer Name="InitialNodeSpace">
  <Value>0xFFFFF0000000</Value>
</Integer>
```

Note that a ConfROM node has *<Address>*, *<pAddress>*, *<IntSwissKnife>*, *<Length>*, and *<pPort>* elements that have the same meaning as with other *Registers* (see section 2.8.3).

The typical implementation will create separate nodes for the *<IntKey>* and the *<TextDesc>* elements that are given the name denoted in the respective entry's *Name* attribute, a *<p1212Parser>* element pointing to the ConfROM node and a *<Key>* element with the respective key values.

2.8.14 DcamLock and SmartFeature

Currently, most standard register layouts are fixed mechanisms, and methods are required to give access to custom features not defined in the standard. GenICam currently supports two access mechanisms.

The *DcamLock* node can retrieve the address of a smart feature exposed according to the DCAM advanced features mechanism. It inherits the elements and attributes from the *Register* node. The following example unlocks an advanced DCAM feature with a <FeatureID> element of 0x0030533B73C3 where 0x003053 is a vendor ID and 0x3B73C3 is a feature ID defined by that vendor. The value 0 in the <Timeout> element means that the feature will not unlock automatically.

```
<AdvFeatureLock Name="BaslerAdvFeatureLock">
  <FeatureID>0x0030533B73C3</FeatureID>
  <Timeout>0</Timeout>
  <Address>0xfffff2f00000</Address>
  <Length>8</Length>
  <AccessMode>RW</AccessMode>
  <pPort>Device</pPort>
</AdvFeatureLock>
```

The *SmartFeature* node can retrieve the address of a smart feature when it is given a global unique identifier (GUID) describing that feature in the <FeatureID> element. It also inherits the elements and attributes from the *Register* node. The following example retrieves the address of a smart feature with a GUID of {5590D58E-1B84-11D8-8447-00105A5BAE55}:

```
<SmartFeature Name="TimeStampAdr">
  <FeatureID>5590D58E - 1B84 - 11D8 - 8447 - 00105A5BAE55</FeatureID>
  <Address>0xfffff2f00010</Address>
  <pPort>Device</pPort>
</SmartFeature>
```

2.8.15 Port

The *Port* object is just a proxy that forwards Read and Write calls to the transport layer. Note, however, that the proxy has all of the properties of a *Node*. For example, it can be "not present." This will tell all dependent nodes that the transport layer driver is currently not open and as a result, all dependent features will automatically also be "not present." Another example would be the implementation of a user set loader. If a user set is loaded from flash ROM inside the camera, all features inside the node graph must be invalidated. This can be achieved by simply invalidating the Port node, which in turn can be automated using a <*pInvalidator*> linked to the *ReadUserSet* feature node.

If the transport layer is restricted to a maximal chunk length or needs special alignment, e.g., quadlet-wise, the transport layer implementation must emulate the IPort interface by breaking down calls longer than the maximum chunk length into multiple calls and must pad calls not fitting the necessary alignment. In order to support certain types of quadlet based interface the <SwapEndianess> element has been introduced: if it reads true the endianess of each quadlet must be swapped before exposing the data to GenICam via the IPort interface.

The *Port* node inherits the elements and attributes of the *Node* node. In addition, it can have a <*ChunkID*> element that identifies a chunk of data in a buffer. This chunk may be mapped to a virtual port that does not give access to a real device, but rather to the chunk of data residing in memory.

```
<Port Name="Device" NameSpace="Standard">
  <ChunkID>4711</ChunkID>
</Port>
```

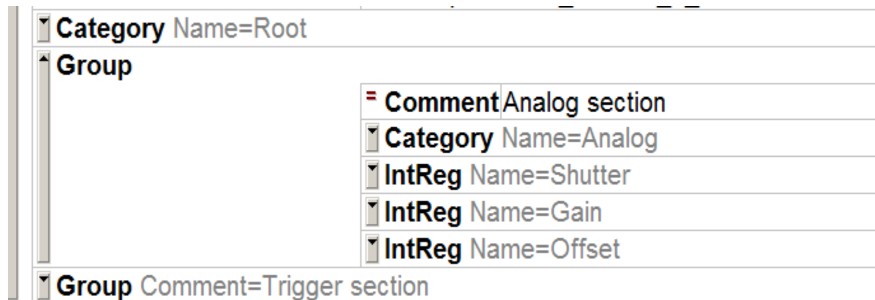
2.8.16 Group element

The <*Group*> element helps to make a large camera description file more readable. The element can be used to bundle blocks of nodes together as shown in the following example:

```
<Category Name="Root">
  <pFeature>Analog</pFeature>
  <pFeature>Trigger</pFeature>
</Category>

<Group Comment="Analog section">
  <Category Name="Analog">
    <pFeature>Shutter</pFeature>
    <pFeature>Gain</pFeature>
```

```
      <pFeature>Offset</pFeature>
    </Category>

    <IntReg Name="Shutter">
      <!-- more elements -->
    </IntReg>
    <IntReg Name="Gain">
      <!-- more elements -->
    </IntReg>
    <IntReg Name="Offset">
      <!-- more elements -->
    </IntReg>
  </Group>

  <Group Comment="Trigger section">
    <!-- more elements -->
  </Group>
```

A typical XML editor will be able to hide the contents of a group as shown in the following screen shot:



The *<Group>* node has a *Comment* attribute, which is displayed by the editor when the group is folded away. Groups can be nested in any depth. They do not have any meaning with respect of the functionality of the camera. If the camera description file is interpreted, they are just stripped off.

2.9 Available Interfaces

This section uses a **pseudo code** notation to list the most important interfaces as introduced in section 2.3. An actual implementation can have more methods per interface, e.g., in parallel to a SetValue(value) method, an operator=(value) method might be implemented that maps directly to the SetValue() method. Also, the actual variable types may differ, e.g., for the pseudo code type string, the actual implementation might be CString, std::string, or something else.

A more thorough explanation is found in section 2.8.

2.9.1 IInteger Interface

- int64 **GetValue**() – returns the value
- void **SetValue**(int64) – sets the value
- int64 **GetMin**() – returns the minimum

- int64 **GetMax**() – returns the maximum
- int64 **GetInc**() – returns the increment
- ERepresentation **GetRepresentation**() – returns the representation as an enumeration

2.9.2 IFloat Interface

- double **GetValue**() – returns the value
- void **SetValue**(double) – sets the value
- double **GetMin**() – returns the minimum
- double **GetMax**() – returns the maximum
- ERepresentation **GetRepresentation**() – returns the representation as an enumeration
- string **GetUnit**() – returns the unit

2.9.3 IString Interface

- string **GetValue**() – returns the value
- void **SetValue**(string) – sets the value
- int64 **GetMaxLenght**() – gets the maximum length of the string

2.9.4 IEnumeration Interface

- string **GetStringValue**() – returns the enumeration value as a string
- void **SetStringValue**(string) – sets the enumeration value as a string
- int64 **GetIntValue**() – returns the index value corresponding to the enumeration value
- void **SetIntValue**(int64) – sets the index value corresponding to the enumeration value
- EnumEntryList **GetEntries**() – returns a list of pointers to the EnumEntry nodes of the enumeration

2.9.5 ICommand Interface

- void **Execute**() – submits the command
- boolean **IsDone**() – returns true if the command has been executed; false as long as it still executes.

2.9.6 IBoolean Interface

- boolean **GetValue**() – returns the value
- void **SetValue**(boolean) – sets the value

2.9.7 IRegister Interface

- void **Get**(uint8 *pBuffer, int64 Length) – gets the register's content to a buffer
- void **Set**(uint8 *pBuffer, int64 Length) – sets the register's content from a buffer

- int64 **GetAddress**() – gets the register's address
- int64 **GetLength**() – gets the register's length in bytes

2.9.8 ICategory Interface

- NodeList **GetFeatures**() – returns a list of pointers to the feature nodes

2.9.9 IPort Interface

- void **Read**(uint8 *pBuffer, int64 Address, int64 Length) – reads an array of bytes located in the device at [Address, Address+Length]
- void **Write**(uint8 *pBuffer, int64 Address, int64 Length) – writes an array of bytes to the device at [Address, Address+Length]

2.9.10 ISelector Interface

- boolean **IsSelector**() – indicates if that node is a selector
- NodeList **GetSelectedFeatures**() – returns a list of pointers to the feature nodes which are selected by the current node.

2.10 Standard Features Lists

The GenApi lets you define abstract features according to their name, interface type, and meaning and make them accessible by a unified API and GUI. However, GenApi does not provide defined sets of features for certain devices such as cameras. These **standard feature lists** are provided separately. GenApi, however, supports these lists by means of the *NameSpace* and the *StandardNameSpace* attributes (see section 2.8.1).

Although the groups creating standard features lists have few restrictions to their work, there are a few features defined by GenApi itself, and they must be present in each standard features list:

Interface	Name	Meaning
ICategory	*Root*	The root of the feature tree
IPort	*Device*	The default port of the device
IBoolean	*TLParamsLocked*	Implements a flag served by the transport layer indication that it is set up for streaming.

3 GenTL Module – Grabbing Images

This GenTL module is still under construction.

4 Acknowledgements

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Company	Represented by
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