



AZ Interface

version 2.2.0

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1 Introduction

AZ Interface (*AZI*) is tool and solution for implementing Java-like interface architecture in LabVIEW projects.

Contrary to other solutions providing Java-like interface architecture, **AZ Interface** is simple while fulfilling basic programming demands.

1.1 Conventions

1.1.1 Shortenings and abbreviators

Abbreviator	Description
AZI	AZ Interface
[aziName]	Any name of AZI
BD	Block Diagram
FP	Front Panel
HD	Hard Disk
[LabVIEW]	Location of LabVIEW in this computer; for example C:\Program Files (x86)\National Instruments\LabVIEW 2016\
[methodName]	Any name of a method
OOP	Object-Oriented Programming
RTE	Run-Time Engine
SW	Software; AZ Interface software
v.	version

1.1.2 Font conventions

- **Bold** is used for anything that appears literally in a LabVIEW environment or in LabVIEW program. For example, for menu, labels that cannot be altered.
- *Italic* is used for terms and messages.
- `Constant Width` is used for values: paths, names, etc.

- **Constant Width Bold** is used for values: paths, names, etc. that cannot or must not be altered.
- [] – brackets surround selectable parts of paths, names, etc.
- *Green Italic* is used for private notes.

1.2 Versions

Version number consists of four values:

1. *version* - altered with major changes causing compatibility and/or conceptual issues;
2. *subversion* – altered with introduction of major changes;
3. *fix* – minor changes, f. ex. a bug fix or minor performance improvement;
4. *build* – has meaning only for developer; f. ex. allows accounting of development packages, special assemblies, etc.

Altered *version* or *subversion* can cause a need in reading updated manual, while altered *fix* or *build* does not affect the way of use.

1.2.1 Version 0.0.0-pre-alpha

First functional version of the toolkit.

The version was presented at European CLA summit in Madrid, 2018.

1.2.2 Version 1.0.0-alpha

The version basically differs from v.0.0.0.

This version is result of brainstorming at European CLA Summit 2018:

- first, the concept was presented as a regular lecture;
- second, pitfalls were extensively discussed/brainstormed with Stephen Loftus-Mercer, National Instruments.
- third, the lecture was repeated and many other experts participated in brainstorming.

I highly appreciate contribution of all participants of these sessions /Andrei Zagorodni

1.2.2.1 Release 1.0.0.0

First public release of **AZ Interface** software.

1.2.2.2 Release 1.0.0.1

Public release including few small fixes.

Main fix: Improved HD folder selection algorithm for newly created **AZ Interface**.

1.2.3 Version 1.1.0-alpha

Reentrant execution of *AZI methods* is implemented. The reentrancy in this version was "limited", see v.1.1 to v.2.1 manuals for concept of limited reentrancy.

1.2.4 Version 2.0.0-beta

Relationships between interfaces and interface-applying classes are altered. Each class "knows" about applied interfaces while interfaces do not "know" about implementing classes.

Upgrading from version 1 to version 2 is described in section 4.4.

1.2.5 Version 2.1.0-beta/alpha

This version basically the same as v.2.0 with added **Consistency tool** (see chapter 5).

Main body of this version is *beta* while the **Consistency tool** is still *alpha*.

Note:

- There are differences between file structures of v.2.0 and v.2.1.

1.2.6 Version 2.2.0-beta/alpha

The version introduces improvements resulting from discussions at European CLA summit in Krakow, 2019.

- Reentrancy limitations are solved.

- Memory management is improved; role of interface method `read_Object.vi` is changed (see section 6.4.3).
- Changes in custom code introduced by **Consistency tool** are bookmarked with tag **#TODO_AZI_autochange**.
- Some bugs are identified and fixed in **Consistency tool**.
- VI description fields are added in method-creating GUI-s.

Main body of this version is *beta* while the **Consistency tool** is still *alpha*.

Note:

- Versions 2.1 and earlier cannot be upgraded to v.2.2 with no effect on custom code. See section 4.4 for details.

1.3 Concept of Interface in other languages

Concept of Interface was developed in some *Object Oriented languages (OOP languages)* to substitute multiple inheritance. Probably the most known of these languages is Java.

Similarly to LabVIEW, a Java *class* can have only one parent *class*; i.e. class hierarchies have tree-like structures. *Java Interface* allows creating "cross-links" between trees; i.e. simulate multi-parent behavior. The concept is illustrated by Figure 1.

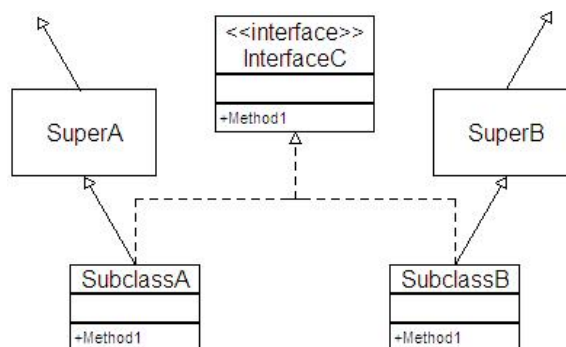


Figure 1 Interface in UML diagram

SubclassA and SubclassB belong to different hierarchical trees. InterfaceC unifies common behavior of these *classes* with no effect on hierarchical positions of classes SuperA and SuperB.

Java Interface provides an own data type allowing to work at corresponding abstraction layer.

Java Interface can be considered as an *Abstract Class* having only abstract methods. Attributes are not allowed in *Interfaces*. Otherwise `InterfaceC` behaves exactly in the same way as any super-class.

2 AZ Interface Background Ideas

2.1 Solutions

AZ Interface (AZI) utilizes capacity of *Call By Reference* node.

Each *AZI* is assembled as a *native LabVIEW class*. No class hierarchies are allowed between *AZI*-s.

Relation between *AZI* and *Class* applying the interface is defined by adding the *AZI* in list of *Friends (Community scope)* of the *Class*.

2.2 Features

AZI-s allow creating abstraction levels independent on hierarchical structures of classes.

AZI-s allow abstraction of functionality independently on implemented OOP model; i.e. same methods of the same *AZI* can be applied in *native LabVIEW classes*, GOOP3 classes, GOOP4 classes, and G# classes.

LabVIEW code created with toolkit can be opened, edited and run without installation of the toolkit. The code is not limited to LabVIEW development environment; corresponding EXE-files can be run under conventional LabVIEW RTE. However, developer must take care about inclusion of invoked code in build specification (that is the same for any LabVIEW code invoked with *Call By Reference* node).

2.3 Limitations

- The code is not imperative; for example inconsistency between terminal patterns is not shown in **Error list** window. However such inconsistency can be resolved using **Consistency tool** as described in Chapter 5.
- No hierarchy between *AZ Interfaces* can be established.
- Current version is tested only for *My Computer* branch of *LabVIEW Project*. Use of the toolkit with other targets is implemented but not verified yet.
- Connector pane of *AZI methods* use terminal pattern 6x4x4x6 only. Altering the terminal pattern would cause errors that are difficult to fix. *Anyhow, using the same pattern through the whole project is a good practice.*
- Connector pane terminals of each *AZI method* should be assigned before the method is applied in one of *classes*. Later changes could require significant efforts. **Consistency tool** (see section 5.3) significantly simplifies this work but...

3 System Requirements and Installation

3.1 Requirements

Current version of the toolkit is developed for LabVIEW 2016 and expected to be fully functional with following versions of LabVIEW.

No additional package is required.

Ask me if you need the toolkit for an earlier version of LabVIEW. I can downgrade the code.

3.2 Installation

No installer is supplied with current version of the toolkit. Files must be manually copied in corresponding LabVIEW directories.

Files belonging to older version of *AZInterface* must be deleted before installation.

3.2.1 File location

Files must be copied in different directories of LabVIEW. The table below refers to [LabVIEW] directory that, for example to,

C:\Program Files (x86)\National Instruments\LabVIEW 2016

Content of the following source directories must be copied into corresponding target directories.

Supplied files	Target LabVIEW directory
GProviders	[LabVIEW]\resource\Framework\Providers\GProviders\
Providers	[LabVIEW]\resource\Framework\Providers\
Project	[LabVIEW]\resource\Framework\project\
help	[LabVIEW]\help\

3.2.2 Recompiling

In some cases files of the toolkit must be recompiled after the copying; f. ex. VIs must be re-saved accounting to new locations of sub-VIs.

To do it open consequently three VIs. These VIs are used only for manual installation. Ignore messages concerning altered file locations. Order of opening could be important:

1. Open LabVIEW.
2. Open
[LabVIEW]\help\AZ Interfaces_1_all_help_AZ_Interfaces.vi
3. Open
[LabVIEW]\resource\Framework\Providers\AZ_Interfaces\
_3_all_providers_AZ_Interfaces.vi
4. Open
[LabVIEW]\project\AZ Interfaces\
_4_all_project_AZ_Interfaces.vi
5. Click menu **File > Save All**.
6. Close all VI-s.
7. Restart LabVIEW.

4 Primary Functions of the Toolkit

Note:

- When working with *AZI* and *AZI*-applying *Class* all involved files must be available for modifications. Remove write-protection from the *AZI*, the *Class*, and all their members.

4.1 Creating AZI

1. Right-click the **My Computer** or any **Virtual Folder** and select menu **AZ Interfaces** > **Create AZ Interface**.
2. **Create Interface** dialog will be opened.
3. Write name of new *AZI*, use other input fields if needed.
4. Click **Create Interface**.

Pink background indicates invalid input value; f. ex. invalid name, name in use, etc.

LabVIEW class will be created in selected location. Newly created *AZI* includes three members:

- **cast_to_Interface.vi** – utility method called only by automatically created methods of *AZI*-applying *classes*.
- **method_refs.ct1** – utility type definition that is part of *AZI* private data.
 - The type definition is also used in automatically created methods of *AZI*-applying *classes*.
- **read_Object.vi** – method is used for back-casting from *AZI* data type to data type of particular class.
 - If the method is used for back-casting, it should be followed with node *To More Specific Class*.
 - The method optionally destroys instance of *AZI* (but not instance of the class), see section 6.4.3.

4.2 Creating AZI method

1. Right-click the *AZI* class in LabVIEW project and select menu **AZ Interfaces > Create Interface method**.
2. Write name of the method in the opened dialog, use other input fields if needed, and click **Create method** button.
3. Open *Front Panel* of the newly created method.
4. Create controls and indicators and connect them to *terminal pattern* of the VI.
 - Do not select another *terminal pattern*; only 6x4x4x6 pattern is supported.
 - Do not disconnect existing *terminals*.
 - ATTENTION: altering *terminals* (number of *terminals*, they assigning in *terminal pattern*, data types) after overriding the method in *AZI*-applying *class(es)* will cause a need in extensive manual work (see section 6.3). **Consistency tool** can help but not solve all possible problems. Thus be careful at this step.
5. Do not edit *Block Diagram* of the *method*.
6. Optionally alter *icon* of the *method*, these changes will propagate in *icons* of corresponding *methods* in *AZI*-applying *classes*.
7. Save the method.
8. Save the whole *AZI* (Select class in the project then right-click menu **Save > Save All (this Class)** or select menu **File > Save All**).

Block Diagram (BD) of the newly created method (see Figure 2) contains default code and terminals of user-created controls/indicators. This *BD* will be automatically altered when the method is first overridden in any *AZI*-applying *class* (see section 4.3.2).

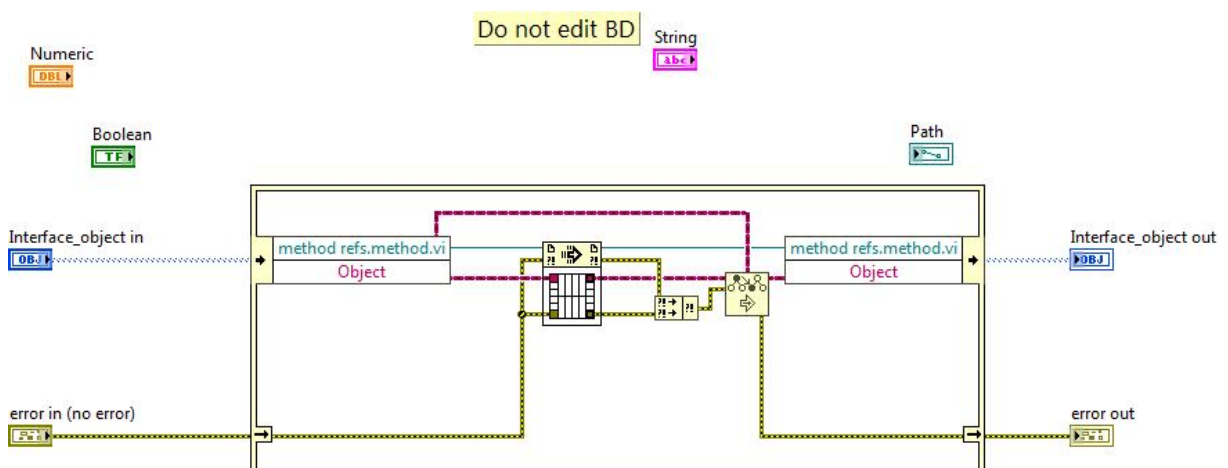


Figure 2 Example of newly created *AZI method*

4.3 Applying AZI and AZI methods to Class

The same dialog is used for applying *AZI* to *Class* and for implementing *AZI Method* in the *Class*.

1. Right-click any class in the project then select menu **AZ Interfaces** > **Apply Interface**.
2. The dialog appears listing all available AZI-s (Figure 3). List **interface methods** is populated with methods of *AZI* selected in list **Interfaces**.

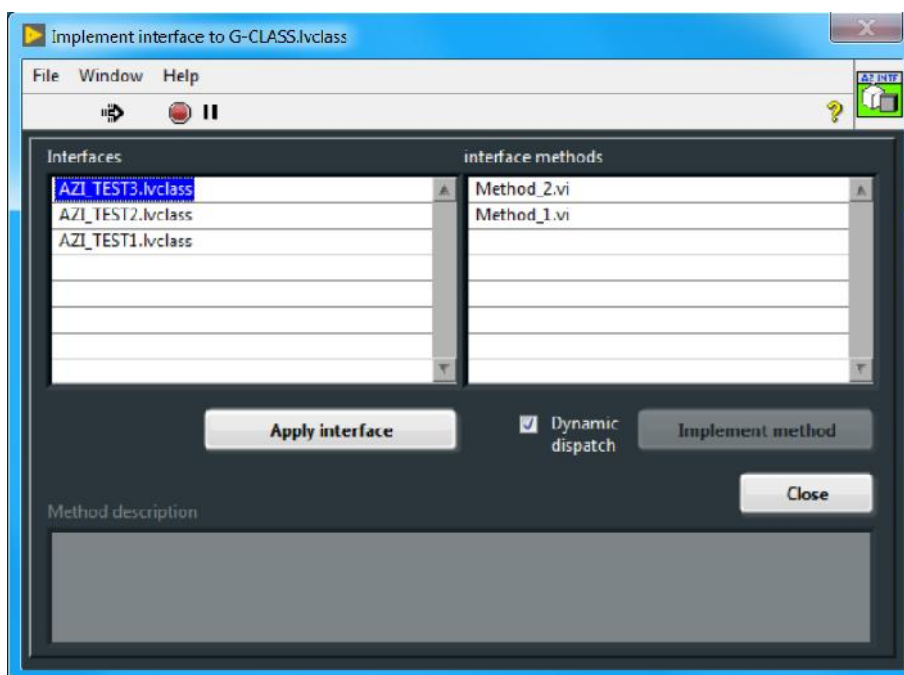


Figure 3 GUI used for applying *AZI* to *Class*.

4.3.1 Applying AZI to Class

1. Select an item from list **Interfaces**. The list shows all *AZI*-s available in the *Project*.
 - If selected *AZI* is already applied to the *Class*, button at bottom of the list is disabled exposing text "Interface is applied". In this case select another *AZI*, continue working with methods (section 4.3.2), or click **Close**.
2. Click button **Apply interface**.

Applying *AZI* to a *Class* results in:

- The *AZI* is added in *Class* lists of *Friends*.
- New method is added to the *Class*:
 - The method is named `cast_to_[aziName].vi`, where `[aziName]` is name of the *AZI*.
 - This method is used for casting of corresponding *Object* to type of the *AZI*. In some sense the casting is similar to one performed by nodes **To More Specific Class** or **To More Generic Class**.
 - The method `cast_to_[aziName].vi` is initially broken. It will be repaired automatically (its *Block Diagram* altered) when any *AZI method* is applied in the *Class* (see section 4.3.2).

4.3.2 Implementing *AZI* methods in *Class*

1. Select an item from *AZI* list **Interfaces** (see Figure 3).
 - List **interface methods** at right-hand shows *methods* available in this *AZI*.
 - If selected *AZI* is not yet applied to the *Class*, button **Apply interface** at bottom of the list is enabled. In this case click button **Apply interface**, select another *AZI*, or click **Close**.
2. Select method in the list **interface methods**. Methods already applied in this *Class* are disabled.
3. Click button **Implement method**.

Applying *AZI method* to a *Class* results in:

- The method is added in the *Class*:
 - The method has necessary terminal pattern.
 - *Block Diagram* of the method is initially empty. All coding of the method must be performed manually.
- Utility method `util_[aziName]_cls_[methodName].vi` is created:
 - Name of the utility method contains name of the *AZI* (`[aziName]`) and name of the actual method (`[methodName]`).
 - The utility method is created automatically and should not be altered.
- *Block Diagram* of `cast_to_[aziName].vi` method is automatically altered.
 - The method is repaired if it was broken (the method being created is initially broken).
- *Block Diagram* of corresponding *AZI method* is rewired if it was not done earlier.

4.4 Upgrading to v.2

Version 2 of the toolkit cannot be used for further development of *AZI*-s created with version 1. If a project contains v.1 *AZI*, right-click will open menu **AZ Interfaces > Upgrade Interface to v2**.

Upgrading v.1. to v.2 does the following:

- Sets access scope of *AZI* method **cast_to_Interface.vi** to be *Public*.
- Empties *AZI*'s list of *friends*.
- Sets internal property of the *AZI* to be v.2.1.
- Upgrade of an *AZI* does not affect code of *AZI*-applying classes. However, some members of these classes could be recompiled at next run.

Notes:

- There is no tool to upgrade *AZI*-s created in version 0. *Anyhow v.0 was not released to LabVIEW community.*
- There is no need in upgrading from v.2.0 to v.2.1.
- Versions 2.1 and earlier cannot be upgraded to v.2.2 with no effect on custom code. The reason is in differently implemented method **read_Object.vi**. Thus previous versions can be upgraded only to v.2.1. V.2.2 of the SW works with AZInterfaces of v.2.1 in the same way as with v.2.2 but do not allow creation of new reentrant methods in the older version.

5 Consistency Tool

Consistency tool provides help with solving discrepancies in *AZInterface*-containing projects.

5.1 Overview

Current version of **Consistency tool** (v.2.2) does the following :

- searches for *AZI* of old versions and updates the version,
- searches *AZI*-applying classes for non-overridden (absent) methods,
- searches inconsistency in method terminal patterns and helps in problem fixing.

The **Consistency tool** is available via menu **Tools > AZ Interfaces > AZ Interface Consistency tool...**

GUI of the tool is shown in Figure 4.

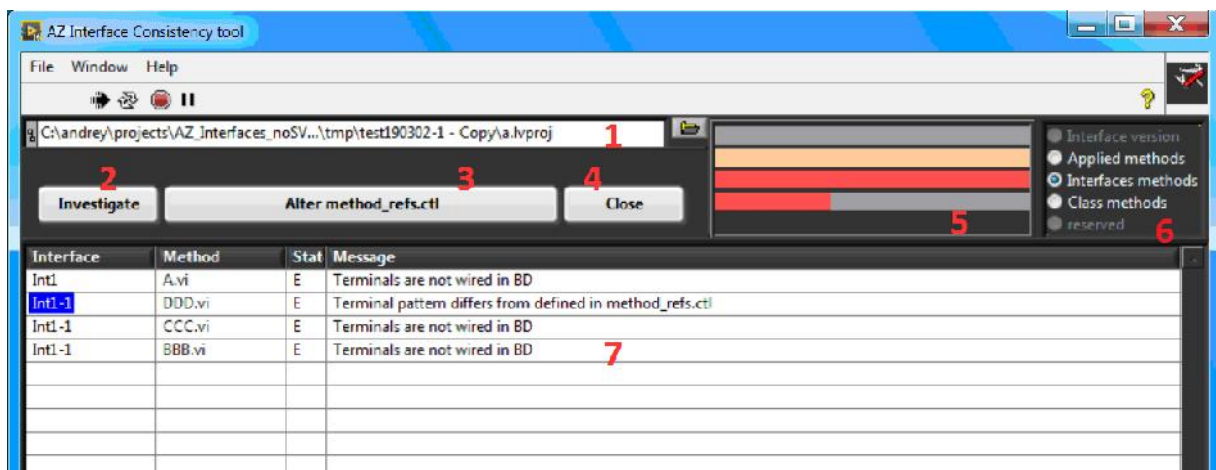


Figure 4 AZ Interface Consistency tool

- 1 – Path to investigated LabVIEW project.
- 2 – Button **Investigate/Stop**.
- 3 – Button fixing selected error (see section 5.3). Text of the button varies.
- 4 – Button **Close**.

- 5 – 2D progress bar (see section 5.2.2).
- 6 – Category selector – radio buttons (see section 5.2.3).
- 8 – Inconsistency report table (see section 5.2.4).

5.2 GUI

5.2.1 Start investigation

Select LabVIEW project in field (1), see Figure 4, then click button **Investigate** (2).

Investigation can be interrupted with button **Stop** (2).

5.2.2 Progress indicator

2D progress indicator (5), see Figure 4, shows progress through steps of investigation (up-down) and through each step (left-right).

Besides it indicates fraction of inconsistent objects. Errors are indicated with red; warnings are indicated with yellow bars.

5.2.3 Category selector

The selector (6), see Figure 4, allows paging through different categories of identified inconsistencies. Found errors are described in inconsistency report table (7)

Each radio button of the selector is located against corresponding bar of progress indicator (5). If no error or warning is found in the category (the bar is green), corresponding radio button is disabled.

5.2.4 Inconsistency report table

The table (7), see Figure 4, presents errors belonging to one category. Errors are abbreviated with letter "E"; warnings are abbreviated with letter "W". Categories of errors are selectable as described in section 5.2.3. The errors are described in following sections.

5.3 Fixing errors

Consequent fixing of errors is recommended. This means: fix errors in interfaces first then attend errors in classes.

Some automatic fixing algorithms are straightforward. Others are described below.

5.3.1 Solving inconsistency in AZI method terminal pattern

The reported error is *Terminal pattern differs from defined in method_refs.ctl*.

Manual altering of AZI method terminal pattern inevitably causes inconsistency in all related method and utilities. Type definition `method_refs.ctl` must be rectified first.

Consistency tool does the work. However, it can affect other members of the project. Rescanning the project (see section 5.2.1) is highly recommended after such a fix.

5.3.2 Solving inconsistency in class method terminal pattern

The reported error is *Terminal pattern does not match pattern of interface method*.

Consistency tool alters terminal pattern accordingly to terminal pattern of the overridden AZI method. I.e. controls and indicators of the class methods are added/removed/replaced.

This could cause errors in BD of the method. To avoid confusions “old” controls and indicators are not deleted but only disconnected from terminal pattern. “New” FP objects are connected to terminal pattern but their terminals are not connected in BD. Thus (ATTENTION!) developer must attend each altered class method and rewire terminals. For the sake of convenience these terminals are bookmarked with tag `#TODO_AZI_autochange`.

6 How to Use

6.1 General example

Use of *AZI*-s can be illustrated by *Block Diagram* presented in Figure 5. Three classes are not hierarchically related while all three apply the same *AZI*.

Objects belonging to three different OOP models are created (GOOP, G#, and Native LVClass) then processed at common abstraction level of the *AZI*. Finally, the objects are cast back to initial class types.

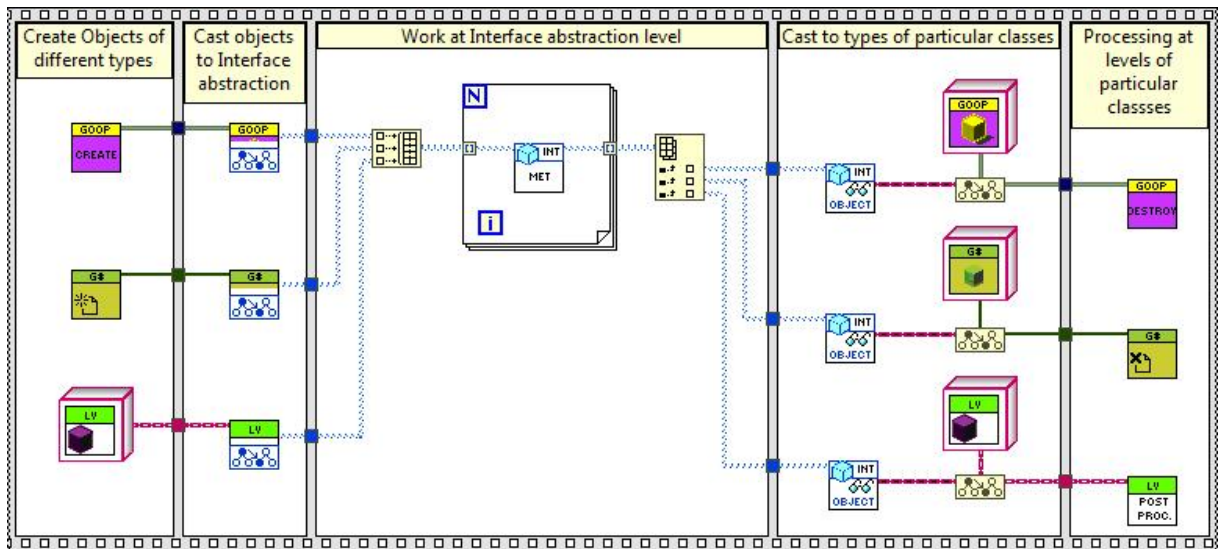


Figure 5 Example of AZI use.

Note:

- Value **clear & close refs** is default for input **destroy Interface** of AZI method **read_Object.vi**. Thus all interface instances are destroyed in fourth step of Figure 5.

6.2 Working with class hierarchies

6.2.1 Sub-classes of AZI-implementing class

Any child of an *AZI*-applying *class* can override *AZI methods* overridden on parent class. There is no need to apply the same *AZI* to each sub-class of the hierarchy.

6.2.2 Two AZI-implementing classes belonging to same hierarchy

A need in applying the same *AZI* to different *classes* of the same hierarchy is rare (see section 6.2.1). *At least I cannot identify such a need.* However; if needed, this can be done changing type of object terminals of all conflicting methods to *Dynamic Dispatch*.

6.3 Altering terminals of AZI method

6.3.1 Modifying terminals manually

Connector pane terminals of each *AZI method* should be assigned before the method is applied in any *AZI*-applying *class*. However, a need in altering terminal signature could arise. Terminal signatures of the following VIs must differ only by type of object terminals:

- *AZI* method must have object terminals of *AZI* type.
- Corresponding class methods must have object terminals of corresponding class type.
- Utility methods `util_[aziName]_cls_[methodName].vi` (see section 4.3.2) must have object terminals of *LabVIEW Object* type.
- Corresponding element (*VI Refnum*) of `method_refs.ct1` (see section 4.1) belonging to the *AZI* must have object terminals of *LabVIEW Object* type; i.e. the element must have the same signature as utility method `util_[aziName]_cls_[methodName].vi`.

6.3.2 Using Consistency Tool to modify terminals

- Create/remove/replace desirable control and indicators in *AZI* method.
- Save the method.
- Start **Consistency tool** and scan the project (button **Investigate**, (2) in Figure 4).

- Select category **Interface methods** (selector (6) in Figure 4); then the *AZI* method exposing error *Terminal pattern differs from defined in method_refs.ctl*.
- Fix the error (button (3) in Figure 4).
- Rescan the project (button **Investigate**, (2) in Figure 4).
- Select category **Class methods** (selector (6) in Figure 4); then one of overriding class methods exposing error *Terminal pattern does not match pattern of interface method*.
- Fix the error (button (3) in Figure 4).
- Open the method and rewire terminals in BD.
- Treat method of next class overriding the same *AZI* method; and so on.

For details see sections 5.3.1 and 5.3.2.

6.4 Instances of classes and interfaces

Note:

- Control of class and interface instancing is especially important for *AZI*-s, which include reentrant methods. Missing to destroy instances of such *AZI*-s result in unused refs left in memory. The destruction is needed even if reentrant methods were not invoked in particular run of program.

6.4.1 Conventional instancing of classes

Conventional instancing/creating objects of by-value LVOOP class is illustrated in Figure 6. New object (instance) is created with class constant or when class wire is branched.

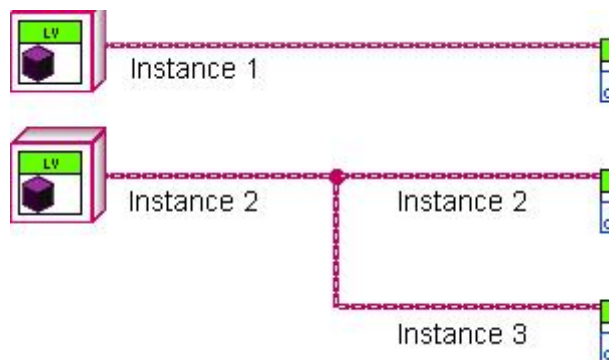


Figure 6 Instancing of by-value class (LVOOP class)

Contrary to by-value classes, instances of by-ref classes (GOOP or G#) are created only with class constructor (see Figure 7). Forking of class wires copies only ref, which points to the same instance of the class.

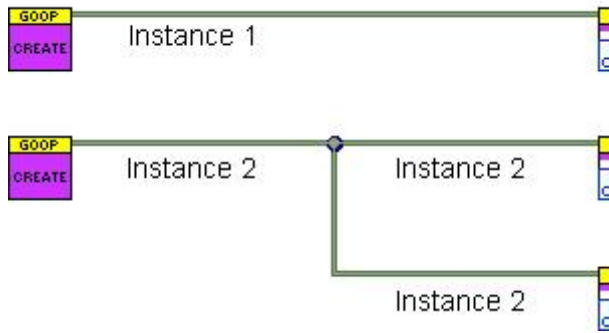


Figure 7 Instanting of by-ref class (GOOP or G# class)

6.4.2 Instanting of an AZI

Each *AZI* instance carries wrapped object of native or by-ref object and references to methods of corresponding class. Thus *AZI* machinery is a by-ref solution. It means that one invocation of class method `cast_to_[aziName].vi` creates one set of references pointing to class methods that override interface methods.

Behavior of particular *AZI* instance differs for different OOP models. Figure 8 illustrates instanting of *AZI* wrapping by-value class. Figure 9 shows instanting of *AZI* wrapping by-ref class.

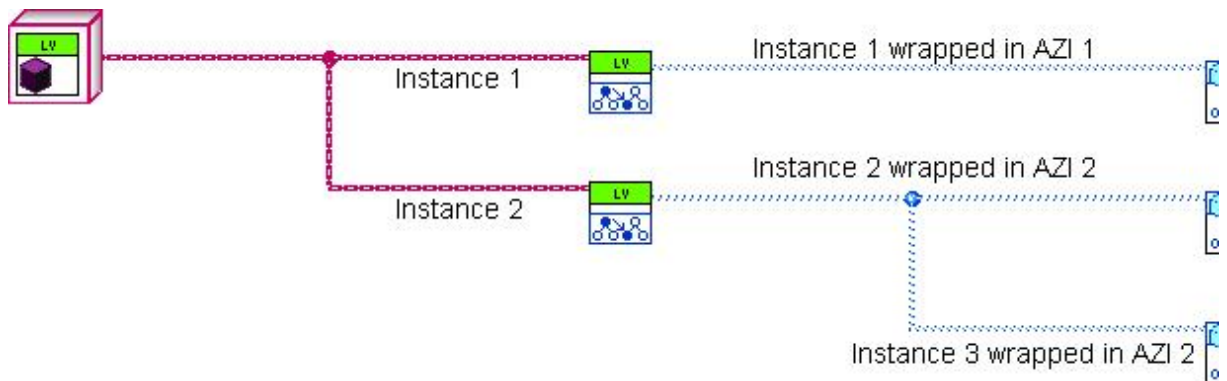


Figure 8 Instanting of a LVOOP class wrapped in *AZI*

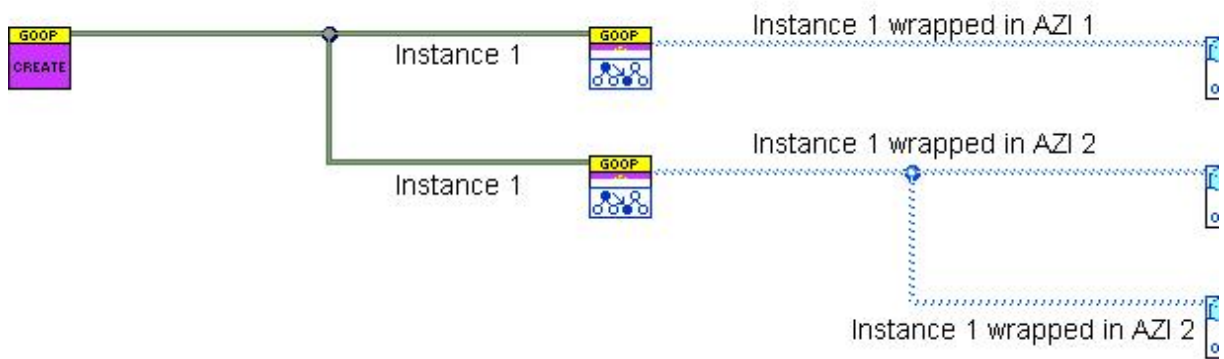


Figure 9 Instancing of a GOOP or G# class wrapped in AZI

6.4.3 Destroying instances of AZI

Because *AZI* uses references, each instance of *AZI* should be destroyed when not needed any more. Method `read_Object.vi` with option **clear & close refs** is used for destruction.

Figure 10 illustrates the concept of destruction.

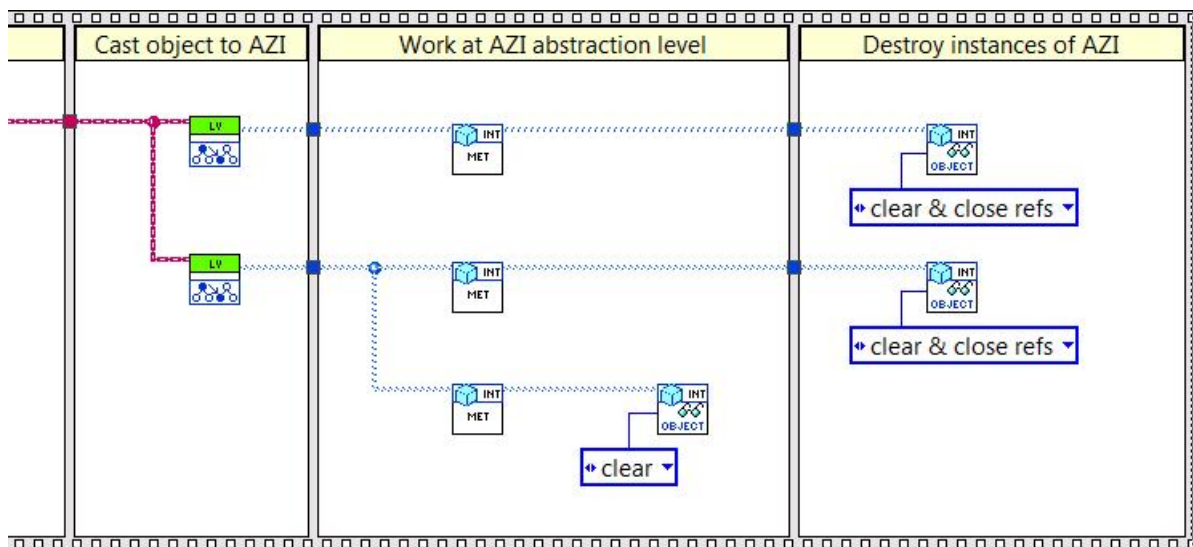


Figure 10 Concept of *AZI* destroying. Each instance created with method `cast_to_[aziName].vi` should be destroyed using method `read_Object.vi`

Notes:

- Option **clear** (used in second step, Figure 10) does not close reference to class methods. It is used for better memory management. This option is useful when

working with by-value LVOOP classes because instances of these classes are created when corresponding wire is forked.

- Input **destroy Interface** defines "level of destruction": **only read** returns the object without destroying instance of the interface; **clear** prevents from holding copy of the object in memory that is specifically important for by-value LVOOP objects; **clear & close refs** also closes refs to reentrant class methods preventing from memory leak that can happen if the same class/interface pair is continuously cast in two or more top-level processes.

6.5 Programming, good programming style

6.5.1 Using read_Object.vi

Method `read_Object.vi` has two purposes:

- conversion from *AZI* data type to data type of particular class,
- destroying instance of *AZI*.

The concept is illustrated in

Figure 11.

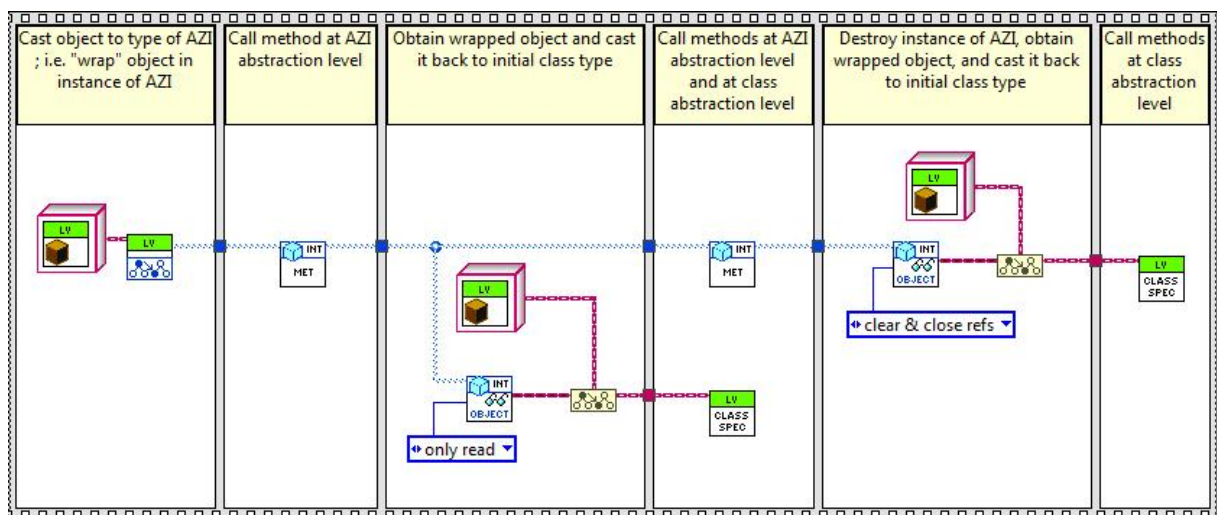


Figure 11 Using `read_Object.vi`

6.5.2 Race conditions

An instance of *AZI* is only a wrapper around conventional object. Thus most cases of race conditions should be resolved considering interactions between objects even if execution is performed at *AZI* abstraction level.

However, destruction of *AZI* can cause race condition as shown in Figure 12. Upper flow in this figure can be eventually completed before execution of other flows. If **read_Object.vi** is executed before middle or/and bottom clone of **MET.vi**, these clones cannot be run.

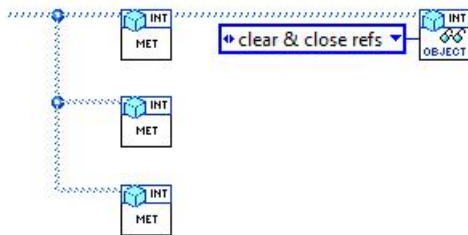


Figure 12 Race condition when destroying instance of *AZI*

The race condition can be resolved in different ways; f. ex. as shown in Figure 13.

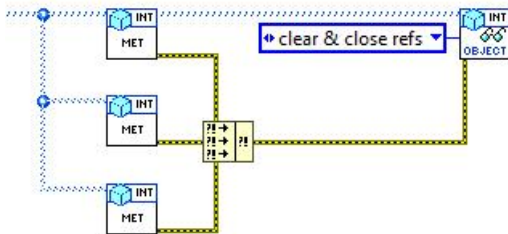


Figure 13 Resolved race condition

6.5.3 Destroying *AZI* – good programming style

Using one call of **read_Object.vi** destructor per each call of **cast_to_[aziName].vi** can be considered as good programming style.

Note:

- Method **read_Object.vi** has disabled automatic error handling. Thus the method can be used even during development of the code; i.e. when some *AZI* methods are not overridden in classes yet.

7 About and Contacts

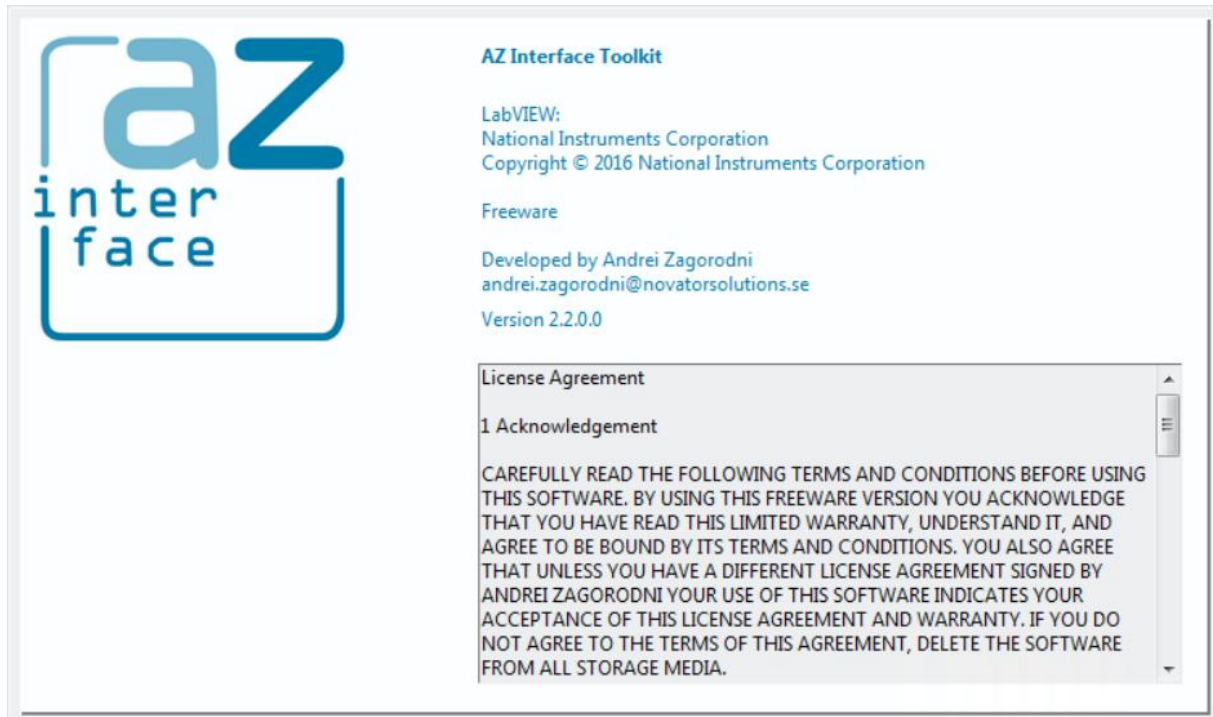


Figure 14 About

7.1 License Agreement

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7.2 Contacts

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Please write **AZI** or **AZ Interfaces** in subject line.

7.3 Support and communications

I shall appreciate feedback about bugs and bottlenecks identified in this SW.

I promise to read your emails and reply within reasonable time. However the project is developed in my evenings and weekends. Thus the "reasonable time" will solely depend on my work load.

You are free to modify code of the software. However I do not promise to support the modified code.

Andrei Zagorodni