Instrument Control at the FRM-II using TACO and NICOS

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At the new neutron source FRM–II in Garching, Germany, the TACO control system, originally developed at the ESRF in Grenoble, France is used for instrument control purposes. TACO provides an object oriented, distributed control system including a clearly defined API. In order to equip TACO with a general user front end, a network based instrument control system named NICOS has been developed at the FRM-II. NICOS is divided into three parts: the NICOS Client, the NICOS Server and the NICOSMethods.

1. Introduction

In this article a survey of the design of NICOS (network based instrument control system) and a comprehensive introduction on how to use NICOS is given.

In spite of the fact that the NICOS client/server, the NICOSMethods and TACO, respectively, are separated program packages which do not depend on each other, the whole software will be regarded in the following as one modular system for control of complex instruments.

Besides the author of this article the following people at the FRM–II were involved: J. Beckmann, J. Krüger, P. Link, J. Neuhaus and W. Wein.

2. The NICOS client

The NICOS client allows the user of an instrument to enter high level commands or even command scripts to control complex operations, as e.g. a series of energy scans of a triple axis spectrometer. Python is used as script language because it is easy to learn and provides powerful commands as well as a simple syntax which leads to short and well readable scripts.

The NICOS client itself is also written in Python (v. 2.1.1) using PyQt (v. 3.0.5) as graphical library.
Almost every Python script can be executed via the NICOS client on the server. However at the moment there are some limitations:

- There is no interface for using the standard input stream. Interactive communication between the Python script and the user is done via the special “nicmd\_prg (prg)” command which starts the program “prg”, waits until it is finished and returns its stdout as Python string. The DISPLAY of the client which started the script is used as standard display for that program.

- It is not safe to use special features as e.g. signal handlers, multithreading and server functionalities. Multithreading is safe, however, when using the internal commands as e.g. the “nicd\_startBgPrg” function to start a process in a new thread.

The main window of the nicos client that appears after startup is displayed in Fig. 1.

![Fig. 1. The main window of the NICOS client](image)

After startup you have to enter the hostname and the port number (1199 by default) of the NICOS server you want to be connected to (connect menu). Then you can login to that server with a user name and a password. After successful login the arrows of the connect button in the main window switch from transparent (grey) to red.

From the main window three major applications can be opened which will be described in the following subsections: The user editor, the program control monitor and the configuration editor.

### 2.1 The user editor

The user editor window includes a simple text editor with common editing capabilities for the user to write experiment control scripts. Single line commands can be entered using the bottom command line with history functionality (cf. Fig. 2). Via the menu or the buttons of the toolbar it is possible to execute a script on the server (run) or to download the currently loaded script from the server to the editor.
It is possible to change the source code of a running script in the editor at lines which have not yet been executed and which are not inside the logical block of the current line (cf. subsection 2.2) and update the script with the new code during runtime.

Clicking on the reload tool button will recursively reload all modules loaded by the server by default. These modules can be specified in the configuration file of the server. Thus it is possible to activate any change of instrument configuration or of instrument control code by one mouse click.

The “simulation” button is not yet implemented, but will follow soon. Clicking on this button will then also start the script on the server but in a simulation mode. In this mode no hardware will be activated, but as many functionality checks of the script as possible are performed to avoid e.g. syntax errors or out of limit errors occur when running the script in real mode.

2.2 The program control monitor

The window of the program control monitor is displayed in Fig. 3. Several informations
Fig. 3. The program control monitor window of the NICOS client

about the status of the NICOS server and the program script that is currently executed by the server are displayed. The window is divided in three subwindows: the script execution monitor, the script output and the variables inspection monitor.

A toolbar with buttons is positioned above the subwindows. The script execution status is indicated by the color of the leftest button: A red color means that a script is currently executed, green means no script is running; yellow means that script execution is interrupted and transparent (grey) means that the client is not connected to a server.

By means of the other three tool buttons a script can be interrupted, continued or stopped by a simple mouse click.

In the script execution monitor (upper left subwindow) the source code of the loaded script is displayed. The currently executed line is highlighted and marked with an arrow.
on the left side. The logical block in which this line is located is marked by blue lines. The update rate of this window can be adjusted.

The output (stdout and stderr) of the script is displayed in the **script output window** (lower left subwindow). Python error messages are displayed here according to the standard Python shell.

In the **variables inspection monitor** (right subwindow) variables and their values can be displayed. It is possible to add and delete values from the script using the “nicd_reg” and “nicd_unreg” commands. Addition, deletion and change of entries are also possible during runtime pressing the “Add”, “Del” and “Edit” buttons. Instead of variables it is also allowed to enter any expression. Double clicking on an entry in the variables list causes the pop up of a window in which the value of the selected variable can be changed.

Another possibility to influence the script execution during runtime is to use the command line input window available from the special menu. Here any command can be entered and executed in the context of the current script.

The manipulation of instrument control scripts during runtime is intended to be used e.g. to extend the range of an energy scan at a triple axis spectrometer or to increase the measuring time at a TOF instrument, when the data collected up to this moment indicate that these changes are useful. In this way beam time will be saved because measurements or parts of measurements do not need to be performed twice.

### 2.3 The configuration editor

The configuration editor has been developed at the ESRF in close contact with the FRM–II. The editor allows to create configuration files for python classes, which define e.g. components of an instrument. This tool has been developed to realize the aim “*configuring instead of programming*” claimed by the NICOSMethods.

The format of the configuration files will be converted automatically by the nicos client to the standard format of the NICOSMethods which are described later in this article. Thus all components of an instrument defined in the NICOS environment can be configured by this editor. It is also possible to configure TACO servers if the servers provide runtime configuration.

### 3. The NICOS server

The NICOS server is a multithreaded tcp stream server written in Python (v. 2.1.1). It provides multiple user login and a secure password authentication procedure. Every login is associated with a security level number, which can be determined by a script
Fig. 4. The configuration editor of the NICOS client

that runs on the server. Thus it is possible to implement execution permissions for users within the NICOSMethods (cf. below).

The server can be configured by a simple configuration file. In this file the Python modules which implement the whole instrument can be specified. Executing the first script will initiate the import of these modules. To reload the modules recursively a deep_reload function of the server is available and can easily be activated using the reload button of the NICOS client. User names can be added in the configuration file and passwords can be set and changed using the “nicd_passwd.py” script.

Python scripts started on the server will be divided into blocks, which are executed sequentially. Before execution a syntax check of the whole script is performed.

By using Python special client classes or a generic Python TACO client class (as provided by the ESRF), it is possible to communicate with TACO device servers directly.

The capabilities of the NICOS server are described in section 2 of this article. Comprehensive information for all server commands available so far are listed in Tab. 1.

4. The NICOSMethods

NICOSMethods are Python classes which represent standard devices of instruments
Tab. 1. List of all available commands of the NICOS server

| command       | description                                                                                                                                 |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| get_info      | returns repr(nicd_prg_info). nicd_prg_info is a dictionary which contains among other entries the loaded script text (prg_text).                         |
| get_status    | returns repr(nicd_prg_status). nicd_prg_status is a dictionary which contains status information of the server e.g.: modules available at startup (modules) |
| get_control_info | returns repr(nicd_prg_control). nicd_prg_control is a dictionary which contains some program control information e.g.: priority of owner (from passwd file) (priority), user_name (login) of the owner (user_name) |
| get_values    | returns a dictionary (as repr(nicd_x)) which contains names and values of all registered items (cf. section 2)                                          |
| get_value (name) | returns the value of the variable “name” in the current namespace of a running prg                                                        |
| set_values (idict) | sets items found in idict.keys() to the specified expressions                                                                                     |
| add_values (ilist) | adds items in “ilist” to nicd_x (registers items, cf. section 2)                                                                                  |
| del_values (ilist) | deletes items in “ilist” from nicd_x (unregisters items, cf. section 2)                                                                               |
| reload_modules | performs recursive reload of modules loaded by default                                                                                              |
| exec_cmd (prg)  | executes a python command in the current namespace of a running prg                                                                                 |
| config        | starts the configuration editor                                                                                                                   |
| update_prg (prg) | updates the python script with prg code found in the “prg” string                                                                               |
| break_prg     | interrupts prg execution                                                                                                                        |
| cont_prg      | continues an interrupted prg                                                                                                                     |
| stop_prg      | stops an interrupted prg                                                                                                                        |
| release_control | releases the control of prg, this means that a program started by a user with a certain priority can be influenced by another user which has a lower priority |
| get_prg       | returns source code of current prg                                                                                                               |
| get_output    | returns output of prg since last call of this function                                                                                           |
| _get_output   | returns output of prg since prg startup                                                                                                          |
| exit          | closes connection to server                                                                                                                     |
| _exit         | closes connection to server without release of prg control (cf. release command)                                                               |

such as motors, digital i/o cards and counters. There are three important advantages to introduce such standard devices:

1. Some general functionalities as e.g. grouping (cf. below) can be implemented in the basic classes and therefore it needs not to be written for each special device.

2. It is possible to define a clear interface for important classes of devices. Such an interface allows to write powerful global commands (e.g. a scan command) which can be used for all the special devices in this class.
3. The interfaces include standard functions for the configuration of the devices. This is needed to set up a general configuration tool as the configuration editor of the NICOS client, which can also be used for any device implemented in the future.

The NICOSMethods framework is written in a way that the code for a new device is easy to write, short and clear.

The root class for all devices is a class called Xable. An Xable object represents a physical or a virtual device, which can be abstracted to control or measure a single physical state of an object (main physical state, MPS), which is represented by the main physical state descriptor (MPSD) such as a position (length, angle), an energy, a temperature, the position of a switch, a count rate or a 2-dimensional intensity distribution. The MPSD can be read and/or set by the main operation of an object (OMO).

In this class the standard interface of devices is defined. The interface definition is described in Tab. 2. It is intended to add a pause () and a getAllPars () command.

There are several parameters defined for an Xable object. The “name” parameter can be used to specify an alias of the instance name of an Xable object. The “adev” dictionary specifies attached devices which are selected by configuration. These devices are linked to hard coded internal names of the Xable object.

With the standard “controller” parameter a device can specify the instance name of its controller object. Such objects are called “exported objects” of the controller. Several different devices can have the same controller. If a controller is specified, the functions of the standard interface are expected to be defined in the controller object. From this point of view a controller offers the possibility to have the same code for different devices. The pointer to the Xable object that calls a method of the controller class will

| command       | description                                      |
|---------------|--------------------------------------------------|
| start (value) | starts object’s main operation (OMO)             |
| read ()       | returns current value of the MPSD of the device  |
| status()      | returns current status of the device (log int, bit array) |
| setPar (key,value) | sets configuration parameter “key” to “value” |
| getPar (key)  | returns current value of the configuration parameter “key” |
| init ()       | initializes the device                           |
| wait (timeout)| waits until OMO is finished; if timeout is specified this parameter overwrites a default timeout |
| stop ()       | stops OMO                                        |
| abort ()      | aborts OMO (emergency halt)                      |
| reset ()      | resets the device to a clearly defined state     |
be added to the argument list. Thus, the controller can determine from which device a function call originates.

The controller together with its exported devices is called “component”.

The controller concept reflects the possibility of TACO servers to export several devices. Attached devices correspond to the possibility of TACO servers to communicate with other TACO servers. So it is evident that the only general difference between TACO servers and NICOS Xable objects is that the Xable objects have no server functionality. Recently a project at FRM–II was initiated with the aim to write a generic TACO server which can add the server capabilities to any Xable object. Then the NICOSMethods provide another way to develop TACO servers:

Build a server by writing a client!

This concept is of special interest since it is very easy to implement a device functionality with the script language Python and the NICOSMethods. The only thing to do is to write a class which inherits the Xable class. In this class for each standard interface function a method named “do” + <name of the interface function> must be written. The following code example implements a class MotorWithSwitch which has two attached devices with the internal names “mot1” and “switch1”. mot1 is a moveable object. A moveable object is an Xable object that defines the alias “move” of the “start” function of the standard interface. switch1 is a switchable object. A switchable object is an Xable object that defines the alias “switchTo” of the “start” function of the standard interface. The MotorWithSwitch class inherits from the class moveable. It represents the functionality of mot1 with the exception that it only starts the mot1 if switch1 is set to “ON”.

```python
from nicm_def import *
class MotorWithSwitch (Moveable):
    typelist = {
        "mot1": Moveable,
        "switch1": Switchable
    }
    def doStatus (self):
        return self.mot1.read ()
    def doStart (self, position):
        if self.switch1.read() == "ON":
            self.mot1.start()
        else:
            NicmError ("switch1 not on")
```
def doRead(self):
    return self.mot1.read()

def doWait(self):
    self.mot1.wait()

Another feature of the NICOSMethods framework is the grouping of Xable objects. To create a group “g” of the Xable objects “a”, “b” and “c”, \( g = \text{XOGroup}(a,b,c) \) has to be written. The command \( g\text{.read}() \) returns a tuple of the return values of the read commands of the objects “a”, “b” and “c”. This works for all common functions.

An important feature of the grouping concept is that a particular controller receives only a single function call even if more than one of the grouped objects are exported devices of the controller. Accordingly the standard interface functions of a controller expect as arguments a list of all devices and a corresponding list of function arguments specified in the group call. The controller methods have to return a tuple with a corresponding number of return values.

Therefore it is possible to implement devices with dependent functionalities which can be handled simultaneously in the controller and initiated with a single function call.

Because of the limited space it was only possible to describe the most important features of the NICOSMethods.

The NICOSMethods are under development since december 2001. Nevertheless up to now the control software of a three axis spectrometer at the FRM–II using TACO and the NICOSMethods is nearly completed. Another instrument started software development with the NICOSMethods and further instruments intend to use this software package. The response of the NICOS users is very positive and as was demanded the development will be continued.