THE NEW TANGO-BASED CONTROL AND DATA ACQUISITION SYSTEM OF THE GISAXS INSTRUMENT GALAXI AT FORSCHUNGSZENTRUM JÜLICH

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Abstract

The new GISAXS instrument GALAXI (Gallium Anode Low Angle X-ray Instrument) has been built by JCNS (Jülich Centre for Neutron Science) at Forschungszentrum Jülich for the investigation of self-organized nanoparticle assemblies. ZEA-2 (Zentralinstitut für Engineering, Elektronik und Analytik 2 – Systeme der Elektronik, formerly ZEL) implemented the new control and data acquisition system for GALAXI. On the base of good experience with the TACO control system, ZEA-2 decided that GALAXI should be the first instrument of Forschungszentrum Jülich with the successor system TANGO. In the first version, the application software on top of TANGO consists of dedicated python scripts, but finally the NICOS-2 software package together with the required extensions and adaptations will be implemented on GALAXI. The design of the new control and data acquisition system is presented and the lessons learned by the introduction of TANGO are reported.

INTRODUCTION

In order to further strengthen its neutron research, Forschungszentrum Jülich founded the JCNS on its own campus with branch labs at the ILL in Grenoble, at the Spallation Neutron Source in Oak Ridge and at the FRM-II, the new high flux neutron source operated by TUM (Technical University of Munich) in Garching near Munich. Over a period of more than 15 years ZEA-2 designed and implemented the control and data acquisition systems of almost all JCNS neutron instruments based on the so-called “Jülich-Munich Standard”. The “Jülich-Munich Standard” is a joint effort of ZEA-2 and TUM to define a common framework for the electronics and software of neutron instruments that is followed by most instruments at the FRM-II [1]. It is based on the TACO [2] control system developed by the ESRF and the extensive use of industrial type front-end equipment, e.g. PLCs, fieldbus systems or remote I/Os. Because TACO is considered to be outdated now, there was the decision to introduce its successor TANGO [3] at FRM-II as joint effort between TUM and ZEA-2. Since the architecture of the new GISAXS instrument GALAXI [4] in Jülich is comparable to typical neutron instruments, it was selected as the pioneer instrument for the first introduction of TANGO. A main advantage of this selection is the location of GALAXI in Jülich, allowing a more direct access by the ZEA-2 developers.

THE “JÜLICH-MUNICH STANDARD”

The “Jülich-Munich standard” is a framework for the selection of technologies and components at each level of the control system. The definition of this framework was motivated by synergy effects and the reduction of spare parts on the shelf. A guiding principle for the framework was to minimize the development efforts and to acquire as much from the market as possible. A key component of the framework is the consistent use of industrial technologies like PLCs, fieldbus systems or decentral periphery in the front end. Main motivations are:

- low prices induced by mass market
- inherent robustness
- long term availability and support from manufacturer
- powerful development tools

A control system according to the Jülich-Munich Standard is organized hierarchically into the following levels:

Field level: The field level is the lowest level, at which devices that are not freely programmable reside, like motor controllers, SSI controllers, PID controllers, analogue and digital I/O modules, or measurement equipment. For all industrial type of I/O modules PROFIBUS DP based decentral periphery is recommended. Siemens ET200S is the preferred one. JCNS predominantly uses the stepper motor controller 1STEP from Siemens.

Control level: The control level resides on top of the process level. Devices at the control level are freely programmable. They must meet real time requirements and guarantee robust operation in a harsh environment. At the control level Siemens S7 PLCs are used, because they dominate the European market.

Process communication: Process communication covers the communication of devices at the field and control level with supervisory controllers or computers. For lab equipment GPIB and proprietary RS232/RS485 connections are unavoidable. For industrial automation equipment PROFIBUS DP is the recommended choice. It is the dominating fieldbus in Europe and is naturally supported by S7 PLCs and many other devices. A major reason for its success is the technological and functional scalability based on a common core as well as the

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programming model, which easily maps to PLC operation.

Experiment Computer: For economical reasons, all experiment computers should be PCs. Linux, being well established in the scientific community, is the only supported operating system. There is no definition of a specific kernel version or distribution. Direct device access should not be implemented on conventional PCs but on CompactPCI systems. CompactPCI allows deploying a variety of existing software in a mechanically more robust platform that fits into 19" racks.

Middleware: Since the framework aims at an inherently distributed system, software support for the transparent distribution of services between systems is required. For this purpose TACO has been selected as the middleware system. TACO is a client-server framework developed for beam line control at the ESRF in Grenoble. In a TACO environment each device or hardware module is controlled by a TACO server. The server offers a set of device-specific functions, which can be accessed by TACO clients via a RPC-based mechanism over a TCP/IP network. To make its functions available to clients, the device server registers itself with the so called manager process and the data base server. The manager in combination with the data base server operates as a name server, which is consulted by clients to get the actual location of a device server. TACO includes a simple database for sharing of configuration data and operational variables between clients and servers.

Application level: On the client side, two variants of application programs are used: Where flexibility is desired and no GUI is needed, the scripting language Python is used. More static GUI applications are implemented in C++, using the "Qt" class library, with TACO access provided by device specific C++ wrapper classes.

TRANSITION FROM TACO TO TANGO

TANGO is a successor of TACO based on the middleware system CORBA. Contrary to TACO, it is consistently object-oriented and removes many of the deficits TACO had. As an example, it provides generic multi-threading, data caching and proper event handling. Additionally, it comes with many standard tools not available in TACO, e.g. alarm system, logging system, code generators for device servers, process data base, graphical editor for the configuration data base, start up tool,.....

As a consequence, TANGO is much more complex than TACO and the code base is huge – e.g. it is not possible to compile a complete TANGO distribution on low end front end systems in a reasonable time. Due to the much higher complexity of TANGO, it was clear that its introduction would be a major effort and that performance and stability could be serious issues.

Therefore we started with a bachelor thesis [5] that analyzed the differences between TACO and TANGO, implemented a small TANGO system for our most important devices and did some performance measurements. In parallel several developers at ZEA-2 studied the TANGO manuals and solved some configuration and administration issues. We found that TANGO was very well documented with a good stability of tools and base system. More important, we found that TANGO had many structural similarities to TACO, e.g. the device access via functions/methods (contrary to process variable interface of EPCIS). As a result, it was easy for the developers to get acquainted with TANGO. Even more important, these similarities enabled a quite standardized approach to porting our existing TACO device servers to TANGO, which allowed reusing a major part of the existing code with minimal effort.

THE GISAXS INSTRUMENT GALAXI

Forschungszentrum Jülich operated the SAXS instrument JUSIFA [6] at DESY in Hamburg for more than twenty years. With the shutdown of the DORIS ring JUSIFA was relocated to Jülich. Based on most JUSIFA components, major mechanical modifications and a MetalJet liquid metal anode x-ray source from Bruker AXS (Fig. 1), the new GISAXS instrument GALAXI was built by JCNS (Jülich Centre for Neutron Science). Main application of GALAXI is the investigation of self-organized nanoparticle assemblies.

Figure 1: Bruker AXS Metaljet Source and first vacuum chamber with aperture and beam attenuator.

The MetalJet liquid metal anode x-ray source in combination with a custom-made parabolic Montel-type optics delivers a high-brilliance and high-intensity x-ray beam with a very low divergence. The instrument operates with Ga Kα photons (E = 9.4 keV). Immediately after the optics, we receive $4*10^9$ photons/s.

GALAXI is a complex instrument with about 30 mechanical axes, a vacuum system and a personal protection system. It is a equipped with a two-dimensional MWPC (multi wire proportional chamber) detector, movable in two degrees of freedom. The MWPC soon will be replaced by a Pilatus solid state pixel detector. The sample table allows the adjustment of the sample in 4 degrees of freedom. The collimation between

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sample table and detector has a maximum length of 5m and consists of 5 movable tube segments in order to support different detector positions (Fig. 2). Definition of the incoming beam is done by 3 4-axes apertures and several additional pneumatically movable beam attenuators. Pin diodes are available for beam monitoring, which are movable too. The MetalJet source is equipped with internal drives for adjustment purposes.

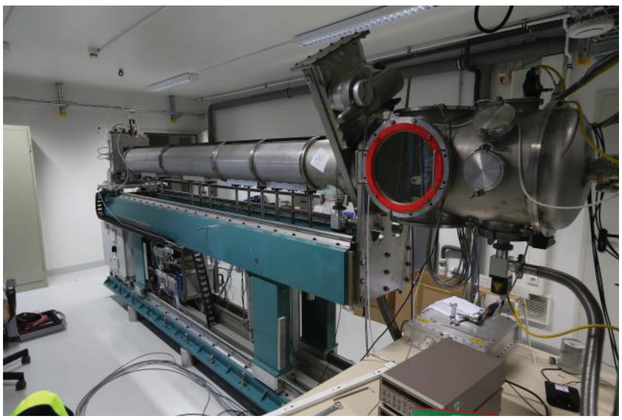

Figure 2: Sample chamber, collimation and detector.

THE GALAXI CONTROL AND DATA ACQUISITION SYSTEM

Physical Architecture of the Control System

According to Fig. 3 the control and DAQ system is implemented as a distributed system with a hierarchical architecture. On top of the system resides the so-called control computer with all application software – GUI-based as well as script-based. Via the experiment network the control computer accesses the "server computers", to which all front end systems (detectors, position encoders, motor controllers, digital IOs, analogue IOs, …) are attached. On the "server computers" TANGO servers are running, which access the peripheral devices via dedicated device drivers.

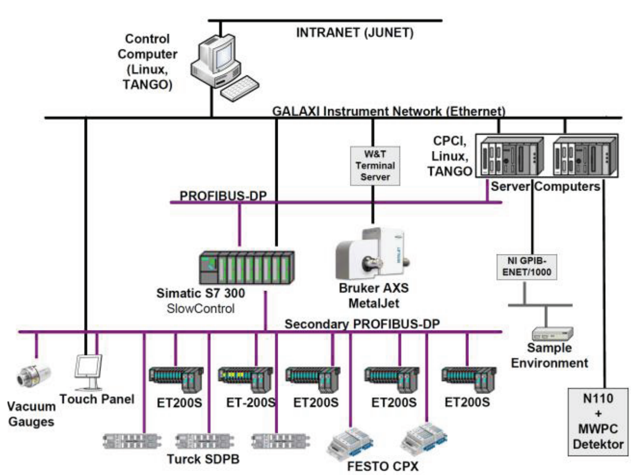

Figure 3: Physical architecture of the GALAXI control and data acquisition system.

The "slow control" peripherals are indirectly connected to the "server computers" via a PROFIBUS segment with the main S7-300 PLC equipped with the failsafe CPU 319F-3 PN/DP. This CPU contains both the "standard" program as well as the failsafe program for the personal protection in parallel.

Figure 4: A decentral cabinet with 2 ET200S systems.

Stepper motor controllers and SSI modules as well as digital and analogue I/Os reside in five modular ET200S decentral periphery systems (Fig. 4), which are connected to the PLC via an additional subordinate PROFIBUS segment. All failsafe signals are connected to special failsafe input modules in one of these ET200S systems. Vacuum gauges and a touch panel for local operation of the PLC reside on the same subordinate PROFIBUS segment, as well as 3 Turck SDPB systems and two modular Festo CPX systems. These Turck and Festo systems with protection class IP65/67 are directly mounted on the diffractometer without any cabinet.

The readout of the MWPC is done via a dedicated readout module developed by ZEA-2 which is connected to a N110 TDC module developed by ESRF.

Software Architecture

As shown in Fig. 5, the implemented software is distributed between three levels of the system hierarchy. All software below the lower dashed line runs on the PLC in the front end. The software modules shown between the dashed lines are running on the server computers. This comprises TANGO servers and device drivers for dedicated HW modules, e.g. detector electronics, counter/timer board, PROFIBUS controller or GPIB controller. The TANGO middleware is the glue that connects the server computers to the control computer, where the client application programs as well as the

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TANGO database server (all above the upper dashed line) are running. Since TANGO is location-transparent, the application programs could run on any Linux-based system.

A thin abstraction-layer implemented in Python above the generic TANGO-Python binding hides many details from the user, e.g. it allows the use of symbolic names and provides the conversion between device units and physical units. This abstraction layer provides a comfortable script access to all spectrometer features. On top of this abstraction layer dedicated python measurements scripts are running, which provide the flexibility required in the commissioning phase. In 2014 they will be replaced by NICOS-2, which will be adapted and extended to the needs of JUSIFA. NICOS-2 was originally developed by TUM for neutron scattering instruments at FRM-II and provides a scripting interface as well as a GUI.

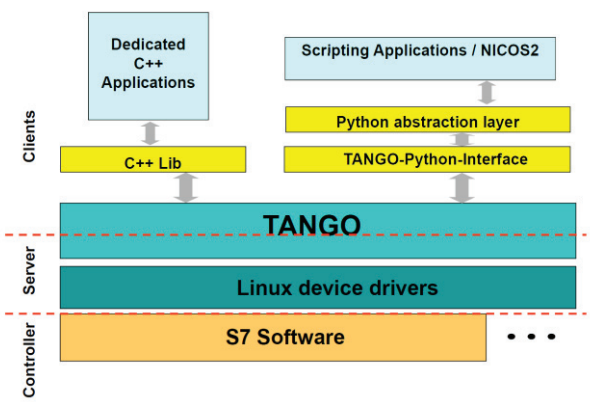

Figure 5: GALAXI Software structure.

CONCLUSION AND OUTLOOK

TANGO has been successfully used for the implementation of the new control and data acquisition system of the new GISAXS instrument GALAXI. The introduction of TANGO as a successor of TACO was smooth without any major problems.

GALAXI is in its commissioning phase now and so there are no final results regarding long term stability. In future, the mechanics of GALAXI will still be further extended and the MWPC detector will be replaced by a Pilatus pixel detector. This change should be no problem, since a TANGO device server for the Pilatus detector is available from the ESRF. The existing top level software based on dedicated python scripts will be replaced by NICOS-2 during 2014.

Due to the positive experiences, TANGO will be used for all future neutron instruments of JCNS and existing TACO-based instruments will gradually be upgraded to TANGO in future.

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