CONTINUOUS SCAN AT SYNCHROTRON SOLEIL

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Abstract

SOLEIL is the French national synchrotron facility, a multi-disciplinary instrument and research laboratory. The experimental facilities of a synchrotron beam center are called beamlines. These consist of a group of three successive cabins where the beam is captured, selected, focused, and directed toward the samples being studied. Each beamline is specialized by type of energy (at SOLEIL, from infrared to X-ray). The so called "Continuous Scan" is a data collection method with a significantly reduced processing time. In a conventional "step by step" scan a large fraction of the scan time is spent waiting for the optical mechanisms to move and for mechanical vibrations to settle after the movement has stopped, as well as for delays imposed by software and by detector readout time. The hardware is based on CPCI format with industrial I/O boards.

CONTINUOUS SCAN GENERIC DESCRIPTION

Definition

The term "scan" is usually employed to describe a process consisting of measuring signals from sensors and their variations with other parameters called actuators which are also varying. There are two kinds of scan: step by step and continuous scan. In a step by step scan, sensor readings and actuator movements (in our case actuators are motors) are performed sequentially. In a continuous scan these operations are performed at the same time and synchronously.

Features

The main goal of a continuous scan is to synchronize sensor data with actuator positions. The requirements are as follows:

- Actuators can be of many different types. In many cases, they correspond to the energy of the beam or a diffraction angle.
- Acquisition must be performed on a large number of sensors as well as different types of signals.
- Data acquisition must run in parallel with motor movements.

As a result, continuous scans are faster than step by step scans, where the motors' movements and the acquisition are done in separate steps. The continuous scan eliminates all the dead time of the step by step mode. In a step by step scan, there are a lot of potential dead times due to the following factors:

- Motor acceleration, deceleration and positioning phases.
- Waiting for optical mechanisms to move.
- Waiting for mechanical vibrations to settle after the movement has stopped.
- Delays due to the software and the readout time of detectors.

Hardware Aspects

The acquisition part (sensors) is based on CPCI format industrial I/O boards, namely PXI 6602 counter boards from National Instruments [1] and CPCI 2010 ADC boards from ADlink [2]:

- The counter boards provide up to eight 32-bit counter/timers (5V TTL/CMOS compatible) and can perform a wide variety of buffered measurements including quadrature encoder and event counter measurement.
- The ADC boards provide four 14 bit simultaneous ADC converters operating at up to 2 MSample/sec.

The motion controllers (actuators) are based on standard industrial boards packaged to SOLEIL mechanical standards by the electronics team. Each crate can control up to 8 motor axes and provides communication over an Ethernet link.

A specific feature of the acquisition part is that one or more counter (PXI 6602 from National Instruments [1]) and ADC boards (CPCI 2010 from Adlink [2]) share the same sampling clock. These boards are chained in master/slave relations (see Fig. 1):

- Slave boards use an external input sampling clock
- The Master board generates a sampling clock for its internal process and distributes it to slave boards.

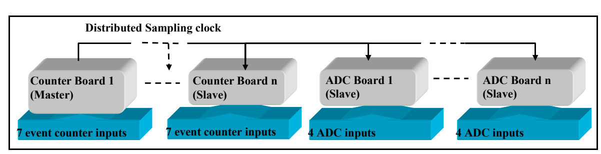

Figure 1: Multi-board data acquisition architecture.

Starting and stopping a continuous scan is controlled by the master board, which controls sampling clock generation and inhibition. For each rising edge of the sampling clock, a set of data is collected simultaneously from the counter and ADC boards (see Fig. 2).

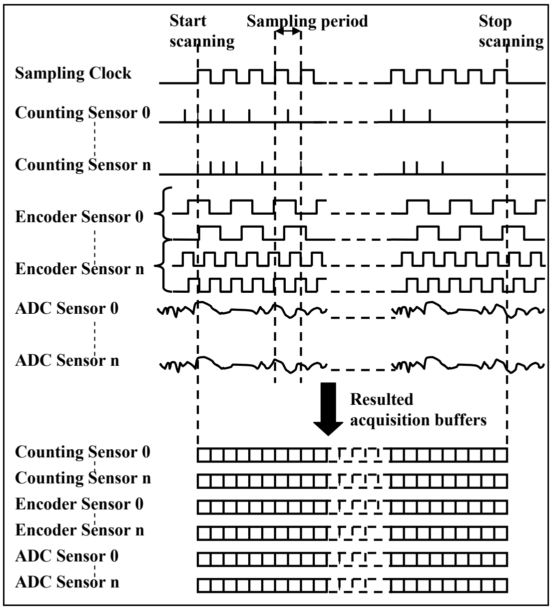

Figure 2: Typical data sampling chronograms.

Software Aspects

The software is a set of modular components that separates the hardware control system from the scan process driver. The entire system is based on the Tango framework [3] in which each of its components is a Tango Device.

For data acquisition boards and motion controllers, the SOLEIL software team has developed generic C++ Tango Devices. These Devices give access to the complete acquisition configuration (number of points during a scan, sampling frequency, sensor number selection, master/slave setup) as well as the acquired data. The following data formats are available from the Devices:

- Buffers of motor position, speed and acceleration from the counter boards
- Buffers of analog values from the ADC boards

On top of the hardware control components, C++ and Java tools more suitable for non-expert users are available. These tools allow acquisitions to be easily matched to motor movements. A Tango Device called a ScanServer acts as a sequencer of elementary actions on Tango Devices (move motor to initial scan position, configure counter board initial position, start acquisitions, start moving motors, sampling frequency and buffer depth settings, and so on).

Another component is the DataRecorder Device that handles the data storage process. Each file of experimental data is recorded on a storage space (which is part of the SOLEIL global data storage system [4]), via the beamline's TANGO control and data acquisition system. The NeXus format has been chosen as the SOLEIL standard file format widely used in neutron science [5] (see Fig. 3).

The last component of the system is the Salsa GUI application which facilitates configuration and monitoring of the whole system (see Fig. 4).

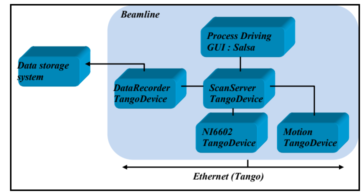

Figure 3: Software architecture overview.

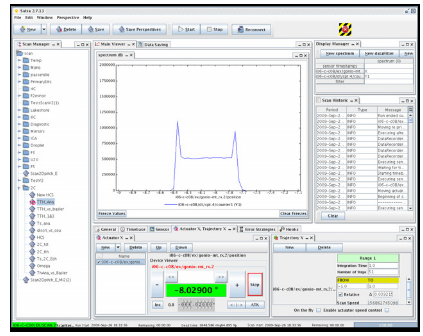

Figure 4: Salsa front panel screenshot.

CRISTAL BEAMLINE APPLICATION

On the CRISTAL beamline, the system has been implemented on the 2 Circles diffractometer experiment and records high resolution powder diagrams. This instrument is equipped with a multi analyzer of 21 point detectors. Pulses produced from detectors (SOLEIL detectors group has developed the amplification and discrimination hardware in order to make signals compatible with the counter board input format) are counted in the NI PXI 6602 board. 21 channels are counted synchronously with the signals from two encoders (see Fig. 5).

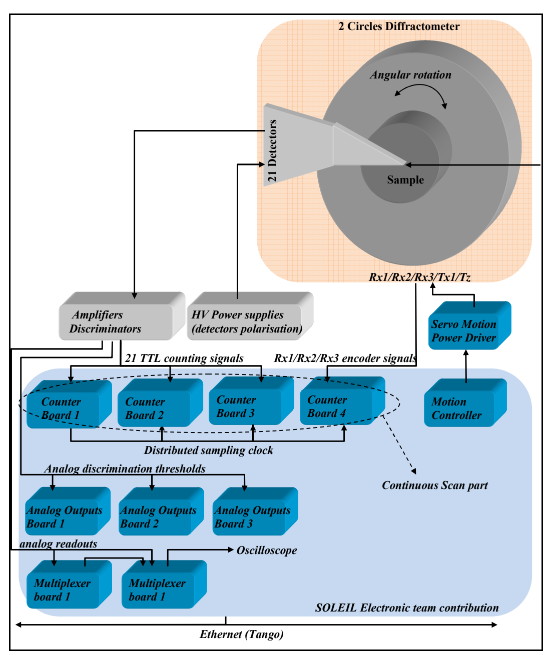

Figure 5: 2 Circle diffractometer architecture overview.

All data are collected into buffers (see Fig. 6) and stored in files.

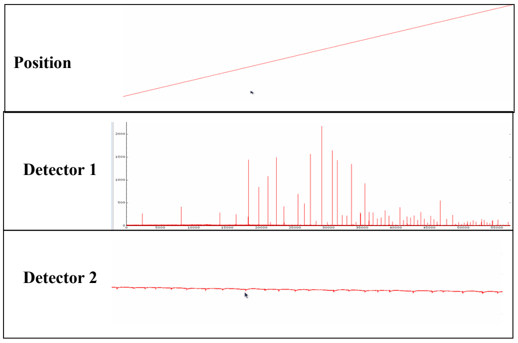

Figure 6: Acquisition buffers example from counter boards.

The continuous scan allows the exploration of a large angular domain (~100°) with very fine steps (~0.002°). The sampling frequency is low (~20 Hz), the scan speed is limited by the diffracted beam intensity. Typically a continuous scan is performed in 45 minutes compared to a step by step scan which would take 4½ hours (see Fig. 7).

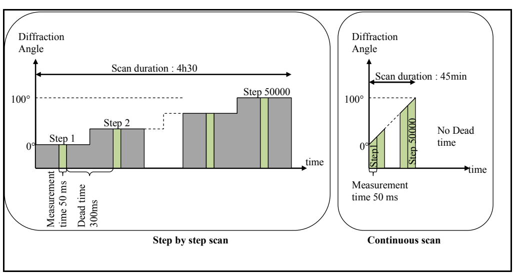

Figure 7: Timing comparison between step by step and continuous scan.

This time gain improves many other aspects, such as reducing radiation damage to the sample and enhancing the reliability of data acquisition.

SAMBA BEAMLINE APPLICATION

The SAMBA beamline has recently commissioned a new monochromator. The highly reproducible and fast movements – indispensable for QEXAFS experiments – are achieved by averaging an oscillating cradle carrying the channel cut crystal. This cradle is set to an average Bragg angle by another conventional goniometer. This cradle is controlled through an eccentric drive operated by a servo motor. Various amplitudes and speeds can be selected. The maximum speed and amplitude of the cradle are approximately 40 Hz and 4°, respectively (see Fig. 8).

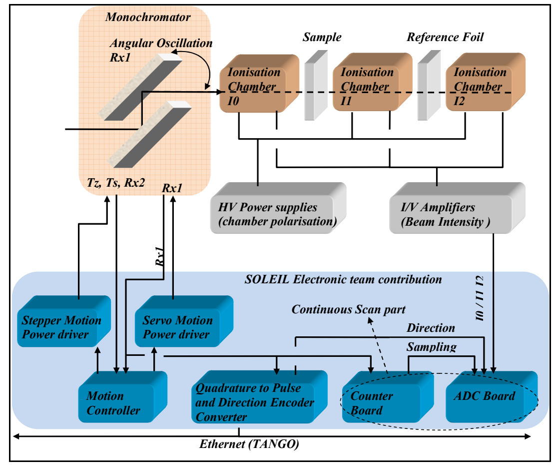

Figure 8: QuickExafs architecture overview.

During a QuickExafs scan, several sensors are sampled synchronously up to 200 kS/s (see Fig. 9); the oscillating cradle position is buffered on a counter board, three intensity monitors (I0, I1, I2) and oscillation direction are buffered on an ADC board.

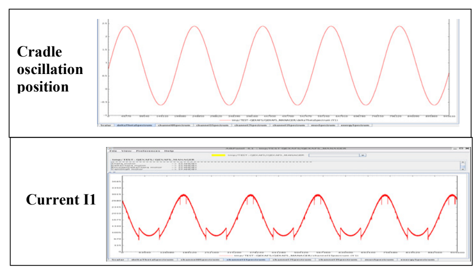

Figure 9: Acquisition buffer of oscillating cradle on counter board and current I1 on ADC board.

CONCLUSION AND PERSPECTIVES

Continuous scan processes have now been deployed on several beamlines. They have been fully commissioned and are now in operation. The hardware involved in such architectures is mainly selected from industrial standards which offer easy implementation, reliability and durability.

New hardware called SPIETBOX is under development, based on a FPGA in order to process encoder signals and ensure more flexibility on continuous scans which could be synchronized with signals generated by it (typically generate triggers on each encoder step or on every change of motor direction).

REFERENCES

[1] National Instruments supplier, http://www.ni.com/
[2] Adlink supplier, http://www.adlinktech.com/
[3] The TANGO framework, http://www.tango-controls.org/
[4] http://www.synchrotron-soleil.fr/portal/page/portal/Instrumentation/InformatiqueElectronique/StockageDonnees
[5] http://www.nexusformat.org/Main_Page