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CAT – Cryogeny Analysis Tools For Online and Offline Monitoring and Analysis of Large Size Cryostats

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Abstract. The Cryogenic Analysis Tools (*CAT*) is a LabVIEW and Root-based Software Package that has been developed in order to study the performances of large size cryostats, where many parameters, input and control variables need to be acquired and analyzed at the same time. The code has a 3-step-based fundamental architecture. First, a LabVIEW class of codes (VIs) collects all the data coming from different kind of instruments and pass these raw data to a dedicated Root module, called *CryoNtuplizer*, which produce custom Root-ntuples (*CryoNtuples*). At the end, a so-called Automatic Analyzer (*AutoANA*) analyzes the *CryoNtuples*, performing a complete and totally customized analysis of the data collected from the cryostat instrumentation. *CAT* is also able to work in stand-alone mode being able, in this way, to perform an offline analysis of the whole cryostat performances.

INTRODUCTION

Large Size Cryostats (LSC) are very complex and delicate systems that have to be operated in real time. Most of them are presently used to cool down large masses to very low temperature (mK temperatures) in order to perform specific and very challenging fundamental physics measurements, see for example ref. [1, 2, 3] and ref. [4] or for other specific tasks. The number of sensors used in order to monitor and control such a systems is normally very copious in number and types, making, all the needed operations on the cryostat, a quite challenging task. To understand, accurately, the behavior of all the parts involved, during, for example, the cool down processes, or during the stable mode run, is the main issue if we do not want to damage expensive instrumentations and if we want to reach the baseline conditions. For this reason, both on-line and off-line analysis is relevant. The former allows monitoring and controlling the cryostat with a dead time that makes possible to operate continuously and in parallel all the several critical parameters and instrumentations. The latter gives information about the whole system, describing the entire process with a more accurate analysis. In both cases, a smart software package able to perform dedicated classes of analysis on the cryostat performances is definitely required.

The Cryogenic Analysis Tool (*CAT*) is a LabVIEW and Root-based software package which architecture has been developed in order to fulfill all these requirements [5, 6].

THE ONLINE DATA ACQUISITION SYSTEM

In most of cases, all the information, coming from LSC, are of different types and they come from several different apparatus very often controlled by a large number of independent devices. Variables as temperatures and pressures

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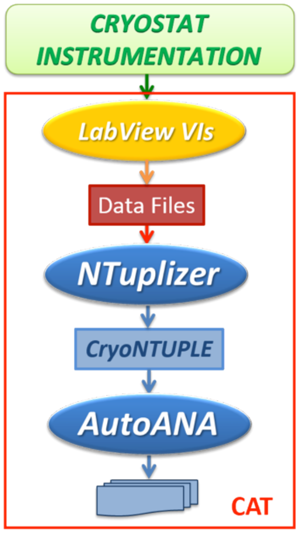
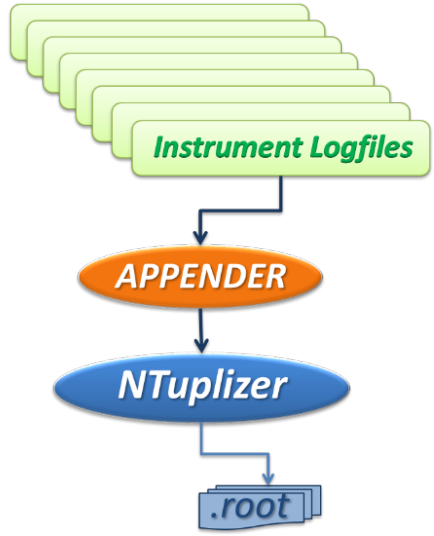


(a)



(b)

FIGURE 1. (a) Flow Chart of the different signals coming from the real instrumentation going to *CAT*; (b) Data taken from logfiles (data files) is then converted in a *CryoNTUPLE* for every single data taking run.

(coming from a quite large number of sensors), parameters coming from gas-compressors, vacuum pumps and a number of different types of Cryocoolers, as well as other quantities are acquired with different methods, being taken from apparatus that use completely different DAQ systems. In order to perform the Online Analysis, the information coming from all those sensors needs to be acquired, converted and stored in real time into Data Files (Fig. 1.a); then they can be processed during the offline analysis.

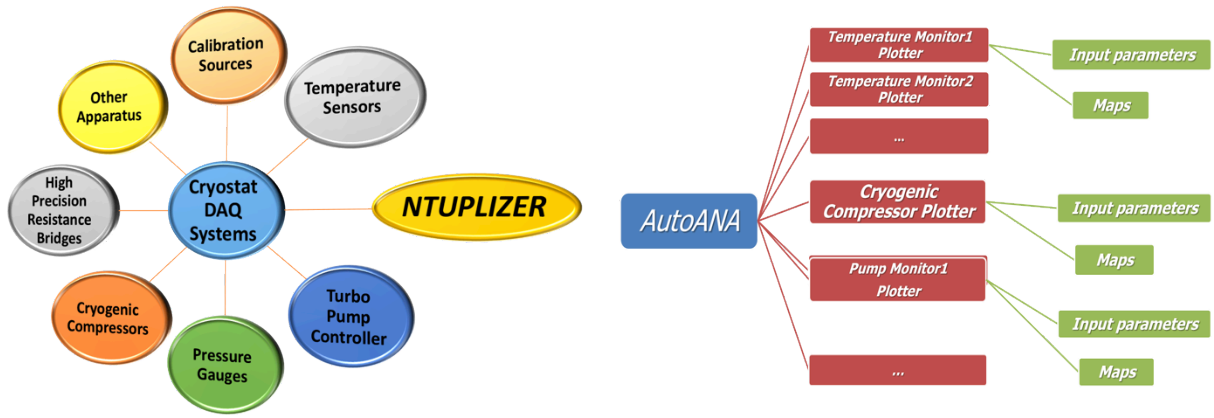
In the case of *CAT*, the Online Data Acquisition System has been based on NI Labview software [5] and it is capable of data exchange among a central workstation and numerous distributed sensors. The developed Virtual Instruments (VIs) monitor and control all the instrumentation, resulting in a bidirectional dataflow. The raw data are received, processed online, displayed on a control desk and finally stored. For this reason, a full Cryogenic System Monitor and Control Package have been implemented. This package can be run not only on Personal Computers but also on several different kinds of industrial platforms. Online Analysis can also be used to calibrate alarms in order to improve safety of both equipment and people.

OFFLINE DATA CONVERSION AND FORMATTING: THE CRYONTUPLES

Matching together such a large amount of information is a challenging task. For this reason, offline data conversion and a hierarchical and dedicated rearrangement of data formats are needed. Moreover, an individual proper timing needs to be adopted. All the previously mentioned operations are performed by a *CAT* Module called *NTuplizer* that collects, select, elaborates, converts and finally stores all the raw data in a single *CryoNTUPLE* (a dedicated root-ntuples with a *.root* file extension), as schematically represented in Fig. 1.b. Every *CryoNTUPLE* contains a list of several Root-Trees, one for each instrument acquired by the whole system (see Fig. 2.a). In every single section, it calculates the absolute time as a difference between the current TimeStamp and the initial TimeStamp. Each *Root-Tree* has several *Root-Trees-Branches* containing all the physical variables acquired type by type, such as time, temperatures, pressures, frequencies, currents, voltages, resistances, etc. The *Root-Leafs*, instead, contains all the relative information coming from each single instrument.

THE AUTOMATIC ANALYSIS MODULE

The Automatic Analysis Module (*AutoANA*) is the core of the whole *CAT* System as schematically represented in Fig. 2.b. *AutoANA* is a package that performs a sophisticated and dedicated analysis for each single instrument. It consists of a set of C++ codes that call, iteratively, a list of functions, generically called *CryoPlotter*. These macros are unique for each kind of instrument and accept, as input parameter, an integer that defines the Instrument ID



(a) (b)

FIGURE 2. (a) The NTuplizer collects, elaborates and stores all the information coming from each single instrument. (b) The AutoANA consists of a routine that calls iteratively a list of functions, generically called CryoPlotter.

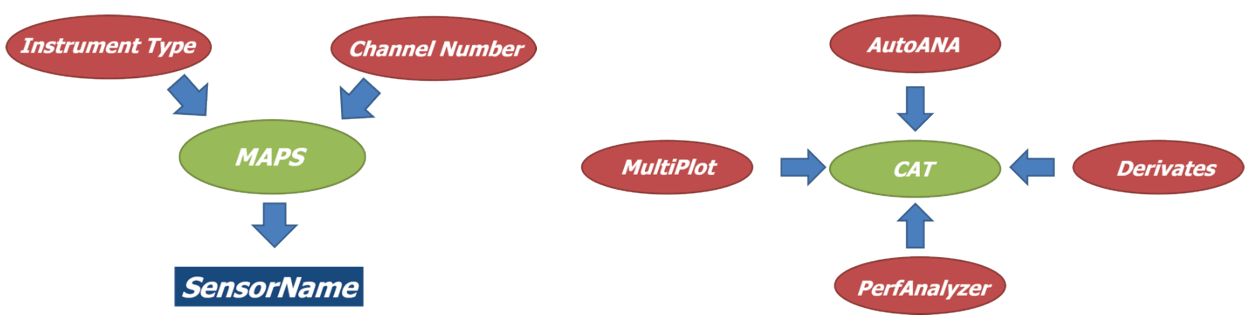
Number. In this way, the user can perform analysis either of the whole system or simply of a part of it. Each *CryoPlotter* opens and reads the *CryoNTUPLE* performing a class of dedicated analysis as required by the operator.

CAT FEATURES AND INPUT PARAMETERS

The *CAT* environment allows a high level of customization, provided by a bunch of dedicated modules. One of them is for example the *CryoSettings* module that takes input variables from external files, also called *CryoCard* input modules. Here the user can define several parameters for automatic or manual analysis studies. More sophisticated and customized analysis and modelization of the instrumentation and of the whole cryostat have been also implemented. Another set of dedicated input modules are, for example, the *CryoMap* modules (see Fig. 3.a and Fig. 3.b) which define variables like sensor names, geometries, calibration tables, offset values and status of each instrument involved in the LSC monitoring system.

OTHER *CAT* FEATURES

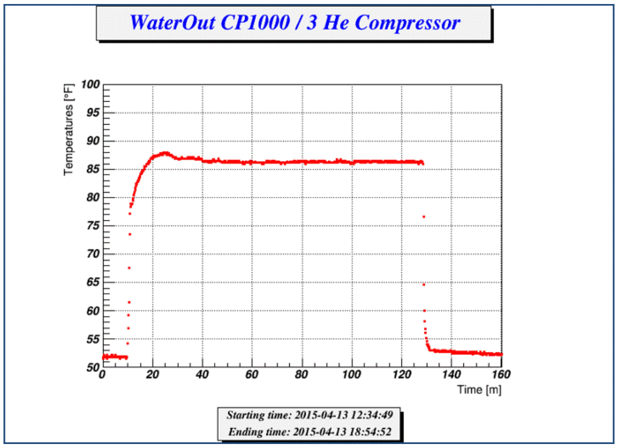
In order to perform dedicated Data Analysis, a set of macros has been developed. These macros can be run independently from the *AutoANA*. The *PerformanceAnalyzer,* for example, analyzes one single sensor, characterizing the performances in terms of efficiency, degradation and so on as a function of the time as well as a function of several other cross parameters, chosen by the user. *AutoANA* routines not only perform several kinds of sophisticated cryogenic analysis but also allow monitoring the behavior of any component related to the whole Cryogenic System. Figure 4 shows just an example of the behavior of different instruments as a commercial ^{4}He



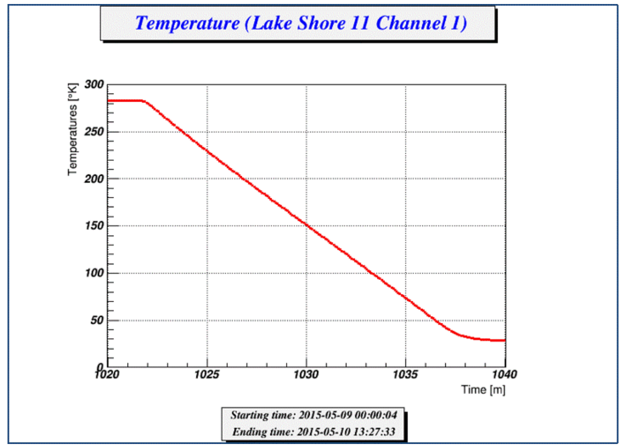
(a) (b)

FIGURE 3. (a) Schematic layout of a *CryoMap* module; (b) Schematic layout of some function called by the principle macros.

compressor used to operate a Gifford-McMahon Cold Head and a generic cryogenic thermometer, that in this case is for example a diode thermometer.



(a)



(b)

FIGURE 4. (a) GM Cold head ^{4}He compressor water outlet temperature distribution; (b) Typical trend of the temperature inside a test cryostat cooled down from a cold head operated from the same compressor used for the plot (a).

SUMMARY

A software package called *CAT*, Cryogenic Analysis Tools, has been developed in order to perform online and offline analysis of Large Size Cryostats and Cryogenic Systems where the number of acquired sensors can be large, of different kinds and acquired from a variety of dedicated electronic instruments. The version 1.0 of the *CAT* Package have been released, it is properly working and has been used to monitor and control the cool down of a very large size cryostat, presently under test. In the near future, an updated version will be released. It shall include more modules able to accept as an input a larger variety of instrument normally used in Cryogenic Engineering. Further improvements will be also the development of a friendlier Graphical User Interfaces (GUI).

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REFERENCES

1. C. Pagliarone, *Status and perspectives of neutrino Physics at present and future experiments*, BPU9 Conference, Istanbul (Turkey), AIP Conference Proceeding (2015);
2. C. Pagliarone (CUORE Collaboration), *Status of CUORE Detector, Results from CUORE-0 Experiment and Future Perspectives*, EuNPC, Groningen, Netherlands (2015);
3. CUORE Collaboration, CUORE Technical Design Report (2009).
4. CUPID Interest Group, http://arxiv.org/abs/1504.03599v1.
5. LabVIEW, National Instrumtents: http://www.ni.com/.
6. ROOT Data Analysis Framework. URL https://root.cern.ch/.