Departmental Report

CERN/AT 2007-29 (MTM)

**A SOFTWARE FRAMEWORK
FOR FLEXIBLE MAGNETIC MEASUREMENTS AT CERN**

P. Arpaia¹, L. Bottura², M. Buzio², D. Della Ratta², L. Deniau²
V. Inglese^{3,2}, G. Spiezia^{3,2}, S. Tiso², L. Walckiers²

A statistical behavioral modeling approach for assessing dynamic metrological performance during the concept design of accurate digitizers is proposed. A surface-response approach based on statistical experiment design is exploited in order to avoid unrealistic hypothesis of linearity, optimize simulation effort, explore systematically operating conditions, and verify identification and validation uncertainty. An actual case study on the dynamic metrological characterization of a Fast Digital Integrator for highperformance magnetic measurements at European Organization for Nuclear Research (CERN) is presented.

1 University of Sannio, Department of Engineering, Benevento, Italy

2 CERN, Accelerator Technology Department, Geneva, Switzerland

3 University of Naples, Department of Engineering, Napoli, Italy

Presented at the Instrumentation and Measurement Technology Conference (IMTC 2007)
1-3 May 2007, Warsaw, Poland

CERN, Accelerator Technology Department
CH - 1211 Geneva 23
Switzerland

30 August 2007

A software framework for flexible magnetic measurements at CERN

Pasquale Arpaia¹, Luca Bottura², Marco Buzio², Domenico Della Ratta², Laurent Deniau²
Vitaliano Inglese³, Giovanni Spiezia³, Stefano Tiso², Louis Walckiers²

¹Department of Engineering, University of Sannio, Corso Garibaldi 107, 82100 Benevento, ITALY. Ph : +39 0824 305804-17, Fax: +39 0824 305840, E-mail: arpaia@unisannio.it

²CERN, Dept. AT (Accelerator Technology), Group MTM, CH 1211 Genève 23, Switzerland.
Ph : +41 22 76 76635; Fax: +41 22 76 76230, E-mail: {Luca.Bottura-Marco.Buzio-Domenico.Della.Ratta-Laurent.Deniau-Stefano.Tiso-Louis.Walckiers}@cern.ch.

³ Department of Engineering, University of Naples, Federico II, Via Claudio, Napoli, Italy; CERN, Dept. AT (Accelerator Technology), Group MTM, CH 1211, Genève 23, Switzerland, E-mail: {Vitaliano.Inglese-Giovanni.Spiezia}@cern.ch.

Abstract – At the European Organization for Nuclear Research (CERN), a Flexible Framework for Magnetic Measurements (FFMM) has been proposed for managing different batch magnetic tests. Such a system is aimed at creating a test platform, integrating new hardware and software, for satisfying a wide range of measurement requirements, variable and evolving during the time. In this paper, first the conceptual project of the framework and its multi-layer architecture are presented. Then, the preliminary implementation of the lowest layers is described.

Keywords: Accelerator measurement systems; Magnetic variable measurement, software reusability.

I. INTRODUCTION

In industrial world, the need for a framework supporting the user in developing software for new measurement applications is widely recognized [1]-[5]. In particular, the new generation of test frameworks fosters the requirement satisfaction of multiple applications, as well as the insertion of new technologies for additional coverage in the future.

Bosch was one of the first to develop the concept of software framework in the measurement field, by building up an object-oriented platform to provide a core for a wide range of test applications [6]. National Instruments has invested in this also, by developing a tool driving the user to assemble software modules, implemented in different environments (e.g. C, C⁺⁺, LabViewTM, and so on), in order to tune and tailor his own application [7]. However, even if a powerful tool to design measurement applications is provided, the user is not assisted in developing actually reusable software modules.

At the European Center for Nuclear Research (CERN), in the years preceding the series tests of superconducting magnets for the Large Hadron Collider (LHC), measurement systems were developed under different

conditions and with variable requirements. The result is a number of system characterized by scarce reusability. To face the change of test rate and conditions, an efficient software platform is demanded in order to (i) accomplish a wide range of measurement requirements, evolving during time, and (ii) integrate new and more performing flexible hardware [8].

Up to now, a specific software for magnetic field measurements (MMP-Magnetic Measurement Program) has been used [9]. However, a fixed measurement algorithm is implemented and deep changes in the code are needed to accomplish new measurement requirements. In the search for an improved solution, we considered the Front-End Software Architecture (FESA), that was developed to optimize the task of computer front-ends for all the application interfaces for the LHC control [10]. It is based on the separation between the generic and the specific code to ensure a good maintainability of the code. However, although it provides a good base to develop a new control and/or measurement application, a strict collaboration with FESA developers is still required in order to fully integrate new applications.

At Fermi National Accelerator Laboratory, a new software system to test accelerator magnets has been developed to handle various types of hardware, as well as to be extensible to all measurement technologies and analysis algorithms [11]. However, at to date is still under development and not worldwide accessible.

In this paper, under the scheme of a formal cooperation between the CERN Group of Magnetic Measurement & Test and the Department of Engineering of University of Sannio, a Flexible Framework for Magnetic Measurements (FFMM) has been developed in order to face the requirements of test software flexibility mentioned above. In particular, FFMM supports the user in the development of his own test application by providing: (i) a scheme to be

followed, whose structure is designed to meet the main requirements of different magnetic measurement applications; (ii) object-oriented modules to increase reusability; and (iii) basic rules to allow the user to use the framework without the developer support.

In this paper, in Section II, the conceptual project and the architecture of FFMM are presented. In Section III, the preliminary experimental implementation is described.

II. PROPOSAL

In this Section, (i) *the goal of the project*, (ii) *the basic ideas*, and (iii) *the system architecture* of the FFMM are described.

A. Goal of the Project

The aim of the project is building a flexible framework for magnetic measurement capable of satisfying different requirements of magnet testing. FFMM gathers the requirements about a measurement task to be accomplished from the user, and helps to produce software capable of carrying out the requested task, in compliance with the specified measurement requirements.

With this aim, the framework drives the user to implement main principles of software quality, i.e. flexibility, reusability, maintainability, and good documentation. FFMM can be regarded as a set of rules allowing the user to easily create high-quality software in the field of magnet testing. On the other hand, the produced measurement software is not flexible, since it can be only reconfigured within the boundaries of a specific measurement application. The user defines to which extent the measurement software has to be reconfigurable.

B. Basic Ideas

The realization of the framework goals is based on the following basic ideas: (i) the flexibility is achieved by means of the code reusability: rapid variations of measurement requirements due to the frequent occurrence

of different small batches of tests are satisfied by redesigning software by re-using modules; (ii) reusability is achieved by object-oriented approach and modularity: a suitable design of the code allows modules to be re-used; (iii) incremental building of module libraries: once modules can be reused, a finite application domain will be saturated in a finite time; (iv) standardization of software structure and modules: a definition of code structure and patterns gives rise to the production of standard modules to be reused easily; and (v) predefinition of a software structure of the test program, organized in standard modules: such an organization provides the user about templates to be filled for generating new codes.

C. System Architecture

The FFMM system architecture, based on the above-described basic ideas, is shown in Fig. 1.

The user writes a formal description of the measurement application (*User Script*). The syntactic and semantic correctness of the *User Script* is verified formally by a *Script Checker*. Then, a *Builder* assembles the measurement procedure (*Measurement Program*), according to a predefined *Scheme*, by using a suitable *Software Module Library*. If some modules of the *Scheme* are not available in the *Software Module Library*, a corresponding *Template* is provided to the user in order to generate them, according to the FFMM syntax. Once the *Measurement Program* satisfying the user requirements is assembled, it is debugged and then stored in a database (DB in Fig. 1), in order to be reused.

III. EXPERIMENTAL IMPLEMENTATION

In this section, (i) *the script organization*, (ii) *the software modules library*, and (iii) *the device software representation* of the FFMM are detailed.

A. Script Organization

The *User Script* provides the purpose of the test, a description of the measurement system, in terms of a list of hardware components and their connections, as well as the test algorithm. Furthermore, the extent of re-configurability of the test software to be produced is also defined.

The *User Script* is composed by several phases, suitably identified by analyzing typical tests on accelerator magnets and, more in general, in the measurement domain of superconducting magnets (we have defined specific examples based on rotating coils, fixed coils, Hall plates, and stretched wire): (i) definition of the measurement components; (ii) definition of mechanical connections; (iii) definition of electrical connections; (iv) definition of reconfigurable parameters in the final measurement program; (v) hardware checking; (vi) storing of the measurement parameters; (vii) hardware settings; (viii)

Fig. 1. FFMM system architecture.

Fig. 2. Scheme's architecture.

description of the measurement phases; (ix) preliminary data analysis; and (x) data storing.

B. Software Modules Library

The *Software Modules Library* and the *Scheme* have an analogous organization. The *Scheme* has a layered architecture (Fig. 2), while its single layers have an object-oriented internal organization. In other words, the interaction among objects takes place horizontally, among objects of the same level. The functionalities of the i -th level are realized by the objects of the layer, which in turn can use the functionalities offered by the level $i+1$, through

a suitably defined interface, according to the typical working of layered systems.

However, the layered structure is not rigid. Even if it is not recommended, while programming in a level, the user can exploit the functionalities of all the underlying levels, for the sake of a higher flexibility or debugging.

The *User Script* belongs to level I, and should be written by using only calls to procedures of the next level. In the *Software Modules Library*, level I contains well-established measurement procedures, saved to easily allow their reuse. Level II contains classes which define high-levels functions that are invoked by calls in the script. These classes allow an easy representation of macro-components of the measurement system, namely sets of basic components defined in the underlying layer, and the definition of methods to interact with them.

C. Device Software Representation

In Fig. 3, the object-oriented organization of the bottom level of the *Scheme*, namely the hardware device abstraction, is presented. The class *Device* is an abstraction of all the possible devices involved in magnetic measurements. The class *Communication Channel* manages the various types of communication buses. A further classification is foreseen to distinguish between the different devices, namely motors, integrators, power supply, acquisition cards (DAQ), and so on. Such an organization aims to provide the user by a powerful interface in order to describe its measurement application, even with different hardware components. The skeleton is designed to easily integrate new hardware without deep changes in the code. The code has been developed in C⁺⁺

Fig. 3. UML scheme of the software *Device* with its *Communication Channel*.

because, obviously, it is an object-oriented language and, in addition, can assure a good efficiency at low level to implement critical part code, directly related to hardware.

IV. CONCLUSIONS

At CERN, a new framework for magnetic measurements has been developed to face the new requirements coming out from the end of the LHC series test. The platform allows various measurement applications, characterized by time-evolving requirements, to be generated. To satisfy such requirements, the framework is developed on the object-oriented paradigm and deploys a layered structure organization in the development of the code. This architecture is useful to reduce the development time of new measurement applications and to integrate new software/hardware objects without deep change in the preexisting code for the sake of re-usability.

ACKNOWLEDGMENTS

This work was sponsored by CERN through the agreement K 1322 with the Department of Engineering, University of Sannio, whose supports authors gratefully acknowledge. Authors thank prof. G. Di Lucca for his useful suggestions.

REFERENCES

- [1] P. Daponte, L. Nigro, F. Tisato, "Virtual laboratory: an object-oriented framework", *Proc. of IEEE Instrumentation and Measurement Technology Conference*, Hamamatsu (J), 1994.
- [2] P. Arpaia, "Flexible measurement systems for industrial applications", (in Italian), PhD thesis in Electrical Engineering, University of Naples Federico II, Italy, February 1992, on *IEEE Instrumentation and Measurement Newsletter*, n.120, Summer, 1993, p. 9.
- [3] A. Langella, G. Betta, P. Arpaia, "A Measurement System Expert Configurator the Optimum Assignment of Series-Parallel Connectable Devices", *Measurement*, vol.11, n.2, Apr. 1993, pp.97-105.
- [4] S. Aggarwal, S. Mitra and S. S. Jagdale, "Specification and Automated Implementation of Coordination Protocols in Distributed Controls for Flexible Manufacturing Cells", *Proc. of 1994 IEEE Int. Conf. on Robotics and Automation*, 1994, vol.4, pp. 2877 - 2882.
- [5] Jonghun Park, Jin-Woo Park, Joongwon Woo, Jongwon Kim and Wook-Hyum Kwon, "An Object-Based Run-Time Executive for Control of Flexible Manufacturing Systems", *IEEE Int. Conf. on Systems, Man, and cybernetics*, Vancouver, BC, Canada, 1995, vol. 1, pp. 103-108.
- [6] J. Bosch, "Design of an Object-Oriented Framework for Measurement Systems" *Domain-Specific Application Frameworks*, M. Fayad, D. Schmidt, R. Johnson (eds.), John Wiley, ISBN 0-471-33280-1, 1999, pp. 177-205.
- [7] <http://zone.ni.com/devzone/cda/tut/p/id/3238#toc0> Designing Next-Generation Test Systems Developers Guide.
- [8] P. Arpaia, A. Masi, G. Spiezia, "A Digital Integrator for Fast and Accurate Measurement of Magnetic Flux by Rotating Coils", *IEEE Trans. on Instrum. and Meas.*, 2007, in press.
- [9] P.C. Ferreira, H. Reymond, "Sequence of tests and settings to start a magnetic measurement on MMP 6.5.0", *Internal note*, CERN 2003.
- [10] A. Guerrero, J-J Gras, J-L Nougaret, M. Ludwig, M. Arruat, S. Jackson, "CERN front-end software architecture for accelerator controls", *Proceedings of ICALEPCS2003*, Gyeongju, Korea, 2003.
- [11] J. M. Nogiec, J. Di Marco, S. Kotelnikov, K. Trombly-Freytag, D. Walbridge, M. Tartaglia, "Configurable component-based software system for magnetic field measurements", *IEEE Trans. On Applied Superconductivity*, Vol. 16, N. 2, Jun. 2006, pp. 1382-1385.