LHC SURVEY LASER TRACKER CONTROLS RENOVATION

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Abstract

The LHC survey laser tracker control system is based on an industrial software package (Axyz) from Leica Geosystems™ that has an interface to Visual Basic™, which we used to automate the geometric measurements for the LHC magnets. With the new version of the Leica software, this Visual Basic™ interface is no longer available and we had to redesign the interface software to adapt to a PC-DMIS server that replaced the Axyz software. As this package is no longer supported, we have taken the decision to recode the automation application in LabVIEW. This presentation describes the existing equipment, interface and application showing the reasons for our decisions to move to PC-DMIS and LabVIEW. A comparison between the new and legacy system is made

INTRODUCTION

The Large Hadron Collider (LHC) is CERN's biggest accelerator. Thousands of magnets of different varieties and sizes are used to drive the beams around the accelerator. These include 1232 dipole magnets of 15 m length, which are used to bend the beams, and 392 quadrupole magnets, each 5 to 7 m long, to focus the beams. Prior to collision, another type of magnet is used to 'squeeze' the particles closer together to increase the probability of collisions. As the required tolerances on the geometry [1] of the LHC cold masses and on the positioning of some of its components are very tight, the final steps of the assembly are assisted by 3D optical measurements. From 2001, a Visual Basic™ program written at CERN (ie: Magnet Geometric Measurement – MGM) with direct access to the command library of the Leica Geosystems™ software, called Axyz, executes every sub-routine of the measurement process [2]. To be able to use the geometric measurement program for the LHC lifetime, the upgrade of the software components was decided.

Measuring Sequence

To identify the geometry of the cold mass cold bore tubes, a motor pulls through the tubes a mechanical mole carrying a reflector whose position is measured by the laser tracker (Figure 1). Since the measurement of both tubes requires the displacement of the measuring system with respect to the cold mass, an external reference system is needed to link the different stations. This system consists of a number of fixed points, distributed around the cold mass and equipped with reflectors. The cold bore tube axes are measured followed by an on-line analysis that links the cold mass shape to the virtual theoretical shape. Once the cold mass shape is known with respect to the theoretical reference system, the cold mass components can be aligned with respect to their theoretical position. The main components to be

positioned w.r.t the reference co-ordinate systems are the corrector magnets, the end covers, the cold feet pads and the extremity of the cold bore tubes. The MGM program guides the operators with instantaneous graphical representation of the measured objects and gives indications about the acceptance and the necessity of further adjustments. During the full assembly of the magnets, the relevant information about the cold mass shape and the components position are kept and used to fill in the final report.
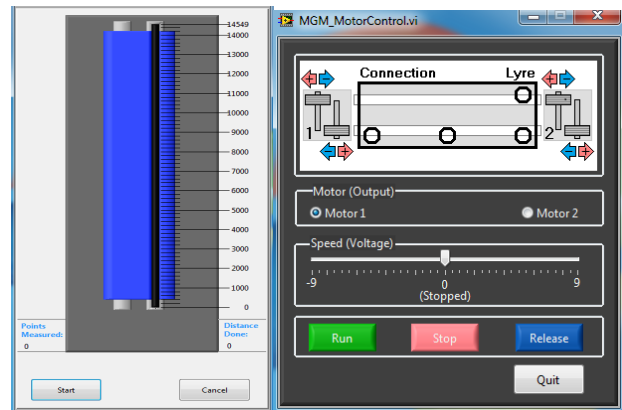

Figure 1: New motor control interface pulling the mole in the magnet cold bore tubes.

Legacy Software and Hardware

The system was running on WindowsXP, using Visual Basic™ 6.0 and Axyz software to control a LTD500 Laser Tracker. The communication between MGM and Axyz was based on OLE commands. The measurements were performed through the Laser Tracker Module (LTM) after having defined many operational parameters. The results were stored in the Core Data Module (CDM), which was accessible by the MGM for mathematical treatment of the raw data.

The list below explains the reason for an upgrade of the system:

- WindowsXP will become obsolete in the coming years.
- Visual Basic™ 6.0, is already obsolete.
- Axyz is obsolete from 2007 and not supported by Leica Geosystems™ from 2011.
- LTD500 are in good working conditions. However they are obsolete devices, thus they may need to be renewed in the coming years with more recent machines.

Software and Hardware from 2011

Following these observations, it was clear that the system had to be adapted. However the end users must not be affected and we have to keep similar GUI and work procedures (Figure 2).
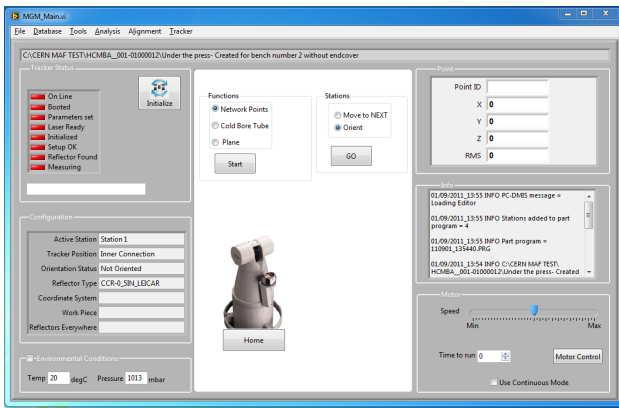
Figure 2: New MGM main panel that keeps the consistency with the previous version [3].

The most expensive tool used is the LTD500. This hardware is obsolete from the manufacturer point of view, but fulfils CERNs requirements to build and repair magnets for the LHC. However, when the need will come to buy a new laser tracker, the MGM will have to be adapted with a minimum effort. The application proposed by Leica Geosystems™ is called PC-DMIS, developed by Wilcox™, both companies being owned by Hexagon™. This application supports custom automation and can be used manually by the operator if special procedures or measurements are needed. PC-DMIS cannot be connected to the laser tracker directly, and a server (ie: emScon server) has to be added in the chain of equipment (Figure 3). The emScon server translates the request from PC-DMIS to commands understandable by the laser tracker.
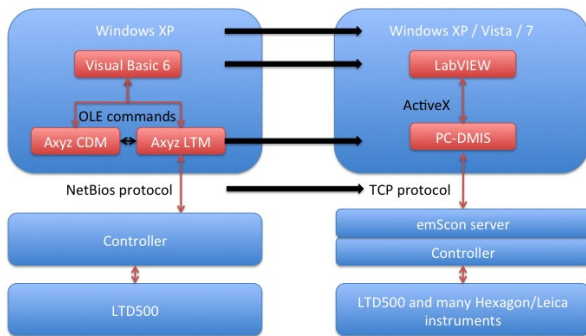

Figure 3: Software and hardware evolution.

The main difference between Axyz and PC-DMIS is that the former is point oriented while the latter is feature oriented. In Axyz the user measures a set of points and can decide later on if they describe a circle, a line …etc… In PC-DMIS the user select a feature and then measure all the points describing it. PC-DMIS is also highly graphical while Axyz is more a textual interface.

The choice was made to develop MGM using LabVIEW™, as it was the most suited to fulfil the requirements of flexibility, adaptability, quality, integration into industrial control software and light maintenance (Table 1).

Table 1: New Structure Pros and Cons

Parts	Status
Windows XP / 7	Can be upgraded to CERN standard
LabVIEW2010	Easy move from one version to another
PC-DMIS	Fully supported by Hexagon™
emScon server	Supported at least until 2017
Controller	Obsolete – can be changed
LTD500	Obsolete – can be changed

Using emScon Direct Commands

Communicating with the emScon server means sending and receiving byte-array datablocks over an asynchronous network connection. Leica Geosystems™ offers an emScon Tracker Programming Interface (TPI) for sending commands directly to the laser tracker from an external application without passing through PC-DMIS. The versatility of the emScon TPI based on standard TCP/IP allows its usage on different operating systems (Windows, Linux, UNIX, Mac…). All measuring functions are available in the emScon library. However, as PC-DMIS will use the emScon server, it is not wise to access emScon with a third party application at the same time, as this will cause conflicts at the server level. Using the emScon TPI would be way lighter for the online sequence, but features such as data storage and mathematical analysis would have to be developed in addition, while they already exist in the PC-DMIS package. For this reason emScon will be used for smaller projects not requiring heavy treatment of data. In any case, this protocol has not been chosen for MGM application.

Using PC-DMIS Commands

PC-DMIS automation gives the ability to automate repetitive tasks within a custom built application running scripts called "part programs". Thus PC-DMIS automation is language independent and provides a list of methods, properties and events for each PC-DMIS automation object. Methods are functions that usually perform actions. Properties allow reading or writing characteristics of an object. Events are routines that get called when certain conditions are met. Performing an action like measuring a point usually involves inserting a command to the script and executing it.

One of the main advantages of using PC-DMIS is that the script describes the measurement sequence being run and stores the data in the same script. This means that an expert can open the scripts, check the raw data as well as the settings used for any measurement and re-run an offline analysis. This has proven to be highly efficient when it comes to debugging the MGM. The scripts are not only used by the expert at CERN, but also by the developers to require help from the hotline (ie: Hexagon™).

Issue Encountered

The original MGM application was developed following specifications for all the modules used to align the magnet components. From 2001 on, tuning of the application has been done on the fly and not always well documented. For this reason, details and specifications for the new version has to be sought for in the VB code. Doing the first automation of a laser tracker in 2001 using Axyz was already a challenge and the developer team had to contact Leica Geosystems™ hotline regularly for information about the hardware and the software. Now, the hardware is under the responsibility of Leica Geosystems™ and the software is under the responsibility of Wilcox™. This dual interface makes it challenging to find the right answer to a technical question involving both parts, even if Hexagon™ is managing both teams.

PC-DMIS scripting has mainly been made to automate tasks, still showing its main user interface to the operator. However, the task automation had to be transparent for the end users. A large amount of work was needed to find workarounds and to be able to play the measuring sequence in the required way.

PC-DMIS is a high level application capable of interfacing lots of different hardware and contains specialised modules for many companies. This gives thousands of objects that can be selected. Magnet manufacturing is a very narrow fields and MGM is making use of a small part of this application. For this reason, it is sometimes challenging to point out the right methods, properties or events to be used

Some functions have been added into PC-DMIS automation following requests from companies or from CERN. For instance, the function called "bundle", used to link measurement from several laser tracker positions, was only accessible in manual operation in PC-DMIS2009 while it was a built-in feature with Axyz. From PC-DMIS2010 this feature is also accessible from the automation mode on our request.

Speeding Up Development and Maintenance

Designing the MGM with Visual Basic™ in 2001 was a real challenge. Not for the code writing itself, but the user interface and all the graphical goodies were all homemade. The mathematical treatment and graph display was taking so long to be developed in Visual Basic™ that it was already decided to develop separate modules in LabVIEW™ for these purposes. Now that LabVIEW™ has been chosen for the main application, access to the ActiveX component are just as easy as with Visual Basic™. However, the calculations, displays and data storage were already built-in functions that only needed to be arranged together.

To ease the development, a LabVIEW™ to PC-DMIS library of drivers has been created including the main functions required for the MGM. Then for each alignment module, the developer will not have to go through the entire PC-DMIS library again. If a desired function is not available, it can easily be added to perfect this

LabVIEW™ to PC-DMIS palette. Each of these components is documented using the built-in online help from LabVIEW™. A homemade tool extracts this help file to create an html file, ready to be published on the web.

At the level of the application, the MGM functions are documented with a text document explaining in broad terms the action performed, and a flowchart describing in detail the action executed (Figure 4).
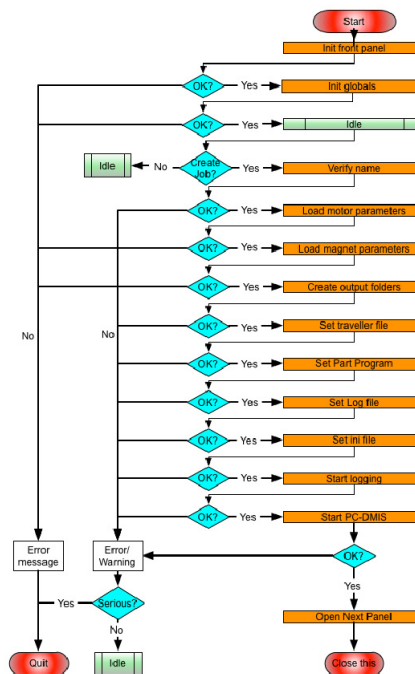

Figure 4: Flowchart for the MGM startup sequence.

A set of configuration files has also been put in place to take care of the hardware and the tolerances for the different types of magnets, as well as a database of points.

CONCLUSION

The existing MGM Visual Basic™ application has given successful results during the magnet construction for the LHC. Now the new system looks promising and the development time has been shortened a lot using LabVIEW™ and a homemade dedicated palette to PC-DMIS. The next step could be to develop a second palette for LabVIEW™ to emScon to avoid using the heavy environment of PC-DMIS for small automations.

REFERENCES

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