DEVELOPMENT OF SMART
A STAND-ALONE SOFTWARE FOR DATA ACQUISITION AT CERN

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Abstract

At CERN, EN-SMM-ASG section (Engineering Department – Survey, Mechatronics and Measurements – Accelerators Survey and Geodesy) is responsible for the metrology and alignment of the accelerator components and their associated beam transfer lines.

As there is no commercial solution for the straight data acquisition of levelling, offset ecartometry and roll angle measurements, CERN developed for the LHC installation, in 2005, the Pocket Field Book (PFB) software [1] running on PDA platform. Hardware obsolescence and evolving needs led this year to the development of a new application called SMART - Survey Measurement Acquisition in Real Time - that allows data collection on Android smartphones and tablets.

This nomadic tool proposes several controls in the field and thus minimizes user mistakes. In addition, the online acquisition mode saves time and eliminates the risk of typing errors. The commissioning of this software before the beginning of Long Shutdown 2 (LS2), covering 2019 and 2020, will bring more comfort to users and increase productivity.

The paper will start with presenting the main functionalities. Then, we will focus on the information technology strategy. The test protocol, which allowed the validation of the software, will be described. It will conclude by outlining the main benefits of the application and most likely improvements planned in the future.

MAIN FUNCTIONALITIES

LHC accelerator and its injectors represents about 22 000 elements to measure and align. As it would be uncomfortable to carry a laptop in the field while moving over the long circumference of the LHC, the SMART mobile application has been specifically developed for the online acquisition of levelling measurements, roll angles and offset distances on CERN installations (*figures 1, 2 3*).

Figure 1: Digital levelling system in LHC.

Figure 2: Offset measurement

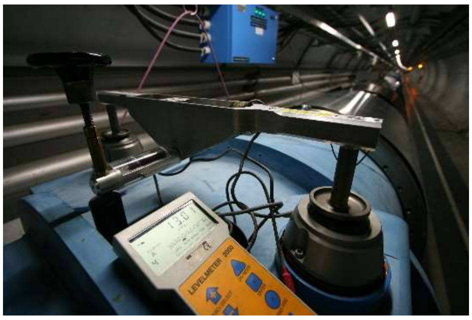

Figure 3: Roll angle measurement

Installed on a smartphone or a tablet with Android OS, SMART allows to enter raw data manually or to acquire them from the instrument by Bluetooth.

The module selection is done on the home page (*figure 4*). Thereafter, the operator is guided through menus and tabs.

Figure 4: Application Home Page.

Job settings

First step consists in inputting job metadata: operators' initials, instruments' serial numbers and operation identification (*figure 5*). Then, the user defines the folder path containing the theoretical coordinates file. The observations sequencing file is optional but could be imported at the same time.

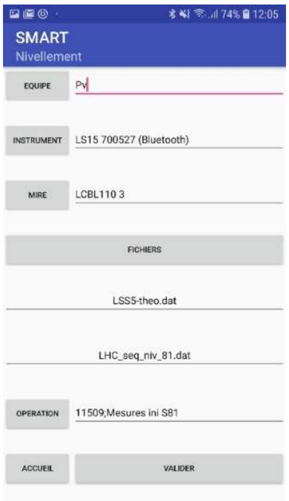

Figure 5: Settings window.

Observation sequencing

Before starting measurements, the user must define a point list to be observed and order it in a sequence (*figure 6*).

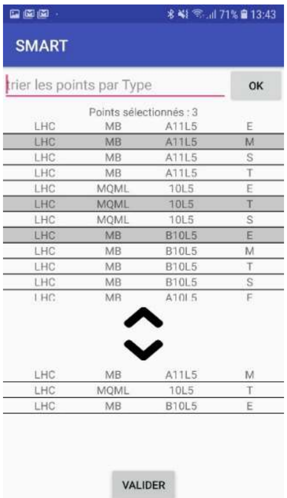

Figure 6: Measurement sequencing.

This sequencing step is done using theoretical points previously loaded and/or by adding new points manually into Points tab (*figure 7*).

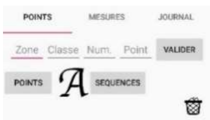

Figure 7: Manual point adding tool.

If a sequencing file has been loaded, the user makes his choice in this one.

Measurements

As soon as the sequence has been created, the operators can launch remote measurements (Bluetooth) or input data manually into the measurement tab as shown in *figure 8*. Points list can always be observed in a different order just by selecting the concerned row.

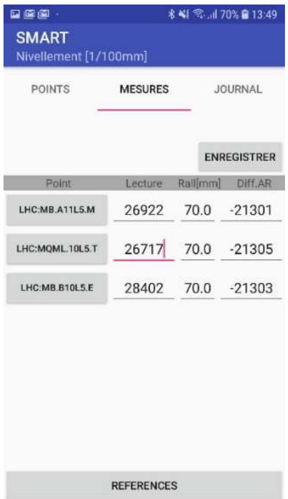

Figure 8: Measurement tab.

Each point is linked to an instrument, as well as an "extension" which gives the height above reference point. As the extension is an attribute of a point, this value is automatically filled using theoretical data file (freely editable field).

The instrument used to make a measurement can simply be modified with a long press on the point name's button.

Concerning the levelling module, SMART application stores forward run settings in memory in order to apply them for return run.

After validation of data input, several indicators help the user to decide if a data recovery is needed or not. Even if a data recovery is performed, old values are stored to keep a measurement log.

Live roll angle adjustment

The roll angle module allows correcting roll angle of elements as they are measured in the field. In order to do this, SMART computes the deviation of the roll angle with respect to the theoretical value. Depending on the result and the associated tolerance, operators may have to adjust the element. In this case, the new measurement performed in the adjusted position is stored in a specific tab (i.e. MES.R tab, *figure 9*).

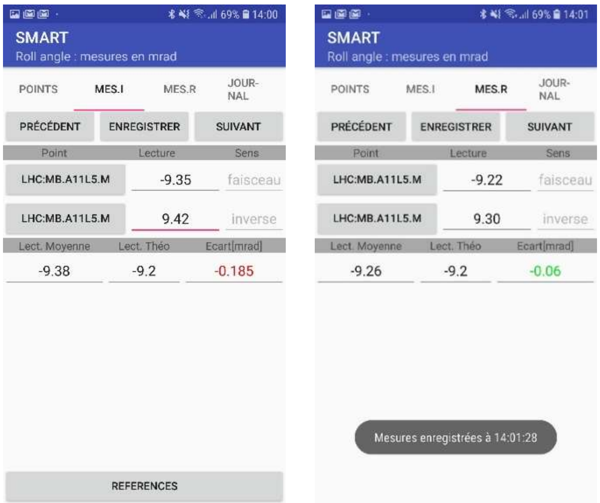

Figure 9: Roll angle measurements before and after adjustment.

Figure 11: Step control.

Measurements display

At any time, the user can display all saved measurements into the Journal tab (*figure 10)*. Data are sorted by date in two scrollable tables corresponding to forward/backward measurements (levelling module) or Before/After displacement measurements (roll angle module). Offset measurements are displayed in a single table.

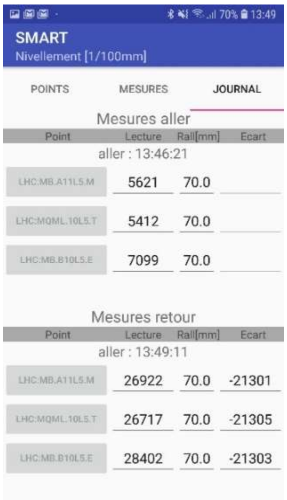

Figure 10: Journal tab showing levelling measurement results.

Levelling measurement checks

For each station, SMART computes the deviation between forward and backward measurements. If the tolerance is exceeded, the user is notified that a recovery measurement is needed.

Furthermore, whenever several points are observed from two consecutive stations, SMART computes the height difference between both stations for each point which allows to detect an instrument movement (*figure 11*). Thus, measurements can be repeated immediately.

Offset measurement checks

Points coordinates read in the theoretical file are used to compute theoretical offset distances between fiducials and a stretched wire. By comparing this result with field observation, SMART gives the user an interesting indication, which allows detecting a rough mistake (typing or reading error). This control is performed in real time for each point (*figure 12*).

Figure 12: Differences between measured and computed offset distances.

Instruments calibration

Although raw observations are definitively corrected during database uploading with the GEODE interface, SMART applies calibration corrections to measurements in the field. Calibration coefficients are read in the calibration file previously loaded.

Several instruments can be used during a same sequence: all measurements are corrected from the instrument calibration and therefore comparable.

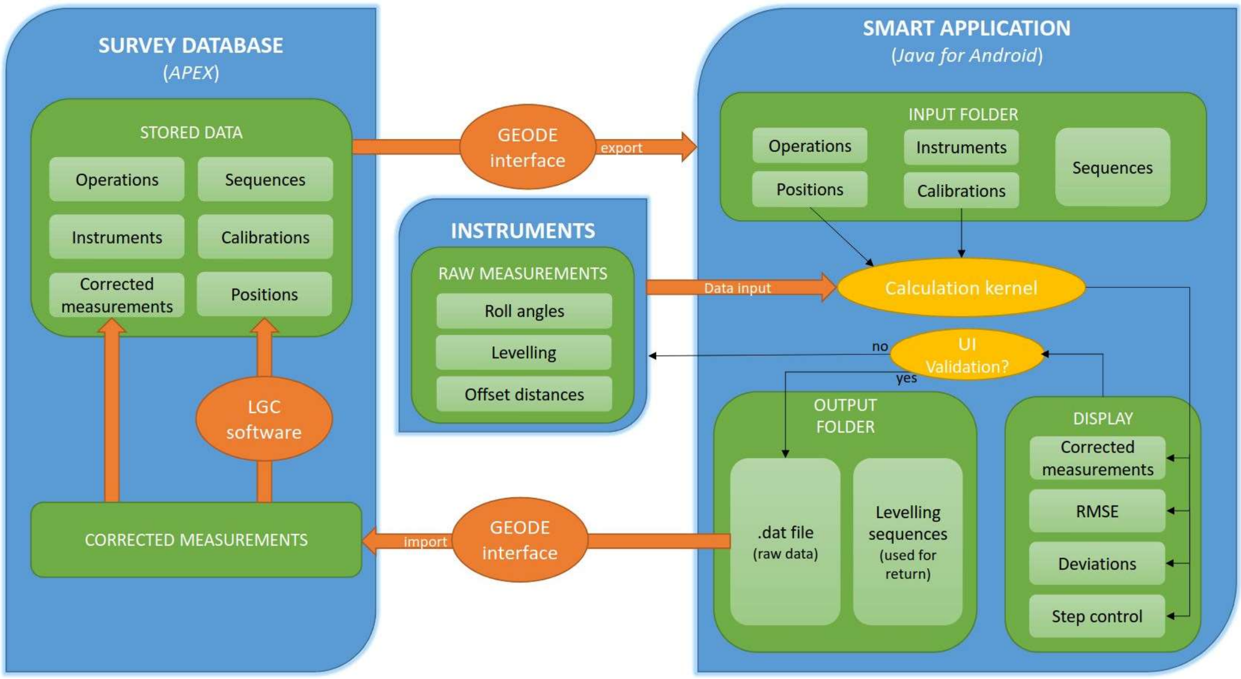

Figure 13: Overview drawing of SMART interactions with instruments and SURVEY database.

Data export and database implementation

SMART application writes an ASCII file in an output folder. Each record is stored on one row including the raw measurement and associated metadata (i.e. measurement date, instrument and extension used, etc.). This file is uploadable in the SURVEY database using the GEODE web interface (*figure 13*). Written in APEX, this interface is used to extract corrected measurements used in least squares calculations.

INFORMATION TECHNOLOGY STRATEGY

The software code has been fully written in Java, the programming language used to develop Android applications. Android apps are usually built as a combination of components that can be invoked individually. For example, an activity is a type of app component that provides a user interface. The "main" activity is what starts when the user taps the app icon. To each type of measurement (levelling, offsets and roll angle) corresponds one specific activity. The activity that specifically handles the levelling measurements also manages the connections and data exchanges with the instruments supporting the Bluetooth communication protocols. This part of code is based on a simple open-source Android library called “Blue2Serial” implementing Bluetooth Serial Port Profile (SPP) communication [3].

In order to use Bluetooth technology, a device must be compatible with the subset of Bluetooth “profiles” (often called services) necessary to use the desired services. A Bluetooth profile is a specification regarding an aspect of Bluetooth-based wireless communication between devices. The Serial Port Profile protocol is based on international standards [4][5] and emulates a serial cable to provide a simple substitute for existing RS-232, including the familiar control signals. Serial Port Profile defines how to set up virtual serial ports and connect two Bluetooth enabled devices.

The format of the textual messages exchanged between the application and the Leica Geosystems levelling instruments is based on GSI-8 [6], a serial data interface for bi-directional communication between devices and computers. GSI uses a simple command structure to read/write values from/to the sensor. Global and instrument specific word indexes (WI) are used to specify various data types. Depending on the type of device used, GSI provides a specific set of commands considering the instrument series functionality. The parsing and decoding of incoming sequences of data blocks (ending with a terminator CR or CR/LF) is implemented in the “Levelling” Android activity.

TEST PROTOCOL AND SOFTWARE VALIDATION

The SMART project has the particularity of having been supported by a team of software developers and surveyors that took care of the testing phase, identifying bugs and proposing improvements. The JIRA tool [2] has been used for bugs tracking and the synchronization between the development team and the survey testing team.

At the end of its first development phase in July 2018, the user community had opened more than one hundred topics, of which 60% have been resolved until today.

MAIN BENEFITS AND IMPROVEMENTS PLANNED

SMART is provided with a user-friendly interface, which ensures a quick familiarization. Besides, various checks throughout the data acquisition help users to detect mistakes. Productivity and measurements quality are therefore improved as well as user comfort.

On the other hand, a number of improvements proposed by users will be implemented in the coming months. Among the most likely improvements planned, the first will be the addition of Bluetooth Low Energy in order to connect the ecartometry device to SMART. Inclinometers could also take benefit from these improvements in the short-term.

A new gyroscopic data acquisition module would allow storing gyrotheodolite measurements by manual input or with a connected mode. The application should store observations (angular measurement, U angle) and metadata (E-value, date, temperature, etc.) for each geographical azimuth.

Several statistical indicators (diffusion, standard deviation) will make possible to check data's compliance with tolerances directly in the field, including reciprocal measurements. A free field will allow recording any event occurring during measurement.

Another module might emerge to store mekometer ME5000 observations. It would be used for manual data input and output file export.

CONCLUSION

SMART has been developed in few months for dedicated CERN activities. The survey requests and methods have been well explain to both external students who work hardly and with passion on a real application development.

As expected for the LS2 period, SMART is ready to replace with success the previous software running on obsolete PDA platform. The testing campaign has led to an intense debugging and has shown that the users are very satisfied of the new hardware and software solutions.

ACKNOWLEDGEMENT

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REFERENCES

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[2] "Jira Software"; https://fr.atlassian.com/software/jira

[3] Open-source GitHub repository (MacroYau developments); https://github.com/MacroYau/Blue2Serial

[4] European Telecommunications Standards Institute; https://www.etsi.org

[5] "RFCOMM with TS 07.10 Specifications", ETSI TS 07.10 standard

[6] "Leica Geosystems GSI ONLINE for Leica TPS and DNA", June 2002; www.leica-geosystems.com