COCOA: General purpose software for simulation and reconstruction of optical alignment systems

P.Arce, CIEMAT, Madrid, Spain
M.Case, U. California Davis, USA

Abstract

We describe a C++ software that is able to reconstruct the positions, angular orientations and internal optical parameters of any optical system described by a seamless combination of many different types of optical objects. The program also handles the propagation of uncertainties, what makes it very useful to simulate the system in the design phase. The software is currently in use by the four optical alignment systems of CMS and it is integrated in the CMS framework, so that it can read the geometry description from simple text files or the CMS XML format and the input and output data from text files or an Oracle database.

INTRODUCTION

There are several types of problems you may find when simulating or reconstructing an optical alignment system. For example, when you are designing a new optical alignment system and you want to

- Propagate errors: Calculate how much the errors of the calibrated parameters and the measurements affect the errors of the parameters we want to measure
- Study redundancies: How much the errors change if some measurement disappears
- Study range: When a measurement will get out of the range of the measuring device is some objects move

Or you may have the problem that your optical system has taken some measurements (2D sensors, 1D sensors, tiltmeters, distancemeters) and the results are not what expected by extrapolating using your calibrated parameters. The reasons may be several, like wrong rotation or position of some objects, or wrong internal calibration of some objects (wedge of a splitter, internal calibration of a distancemeter, deviation when traversing a sensor, ...).

The software to solve these problems can indeed be the same for simulation and reconstruction. The only difference is that for Simulation the measurement is ideal, while for reconstruction the measurement is real

To solve these problems you have to get the equations of how each measurement depends on all those parameters

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M1 = f1(p1, p2,..., pm)
M2 = f2(p1, p2,..., pm)
...
Mn = fn(p1, p2,..., pm)
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where M1,, Mn are the measurements, p1,,pm are the parameters (known and unknown) and fi are non-linear equations. To solve the system of equations you can use a non-linear least squares fit. Indeed to solve a system of equations, you do not have to know the equations, but only the derivatives are needed. The simplest way is to get the derivatives with a numerical method: reproduce a measurement with initial parameters (e.g. propagate a laser until the sensor), move a parameter and see how the measurement value changes and repeat n times moving 1/2i, until it converges.

COCOA

COCOA [1] is a general purpose software to simulate and reconstruct optical alignment systems composed of any combination of

laser, x-hair laser, source, lens, pinhole, mirror, plate splitter, cube splitter, rhomboid prism, optical square, sensor2D, sensor1D, COPS, distancemeter, distance target, tiltmeter, user defined[1]

Each object may have its internal parameters (planarity of a mirror, wedge between plates of a plate splitter, internal calibration of COPS, ...)

COCOA reconstructs the positions, angles or internal parameters of each object from the measurement values and the calibrated object parameters and also propagates the errors of the measurements and calibrations (including correlations).

The first thing you should to do use COCOA is describing your setup. This can be done in a simple text file or using the CMS XML detector description format [2]

Then you should select which of the object parameters are unknown and which are known. For those that are known you should write the best knowledge of their values. Those values can be written in the setup text description file, read from another text file or read from an POOL-Oracle [3] data base.

Then you have to tell COCOA where your measurements are. You can describe your measurements in a simple text file or use as input a ROOT tree in the appropiate format.

To visualize your detector you can produce a VRML (Virtual Reality Modeling Language) file, or use the CMS IGUANA visualisation of XML files.

For detailed studies, it is also possible to define an scan or a random set of values of one or several parameters.

[1] The user can defi ne its own object: tell COCOA how much the light ray will be shifted and deviated for each measurement

USE OF COCOA

COCOA has been extensively used in CMS for several years. It has served first to do most of the design studies that defined the current CMS optical alignment system (see fig 1).

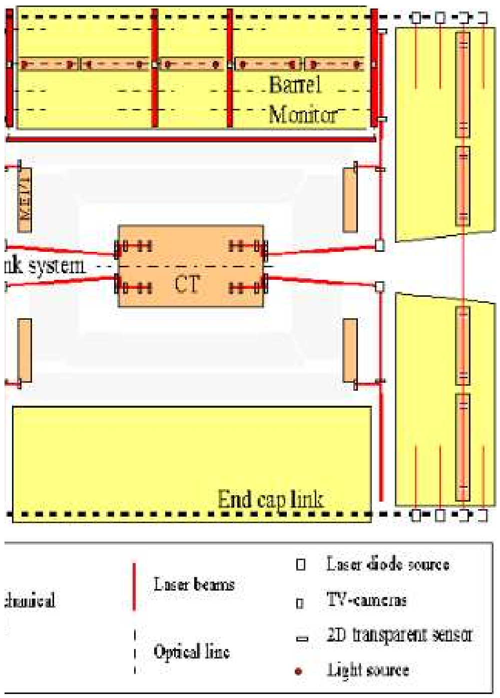

Figure 1: Schema of the CMS optical alignment system

It has also been used for designing and analysing the data of several test benches of the CMS optical alignment system.

The full CMS Link alignment subsytem (3000 parameters) and CMS MuonMuon Endcap alignment subsytems (6500 parameters) has been succesfully simulated with COCOA. The biggest system fully reconstructed with cocoa has been the test in 2002 of afull CMS muon alignment halfplane, with more than one thousand reconstructed parameter. We show in figure 2 we show some of the result and how well they compare with the survey measurements.

In may 2006 it will be used to simulate a third of the full CMS optical alignment system and to will also serve for the reconstruction of displacements at the CMS Magnet Test. COCOA will also be the software that will analyze the CMS optical alignment data and pass the alignment correction to the CMS reconstruction software when the LHC will start to take data.

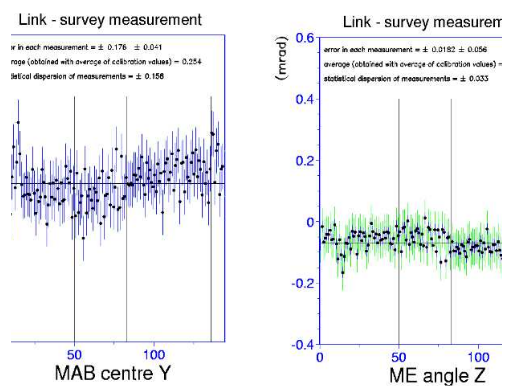

Figure 2: Some of the results of the CMS optical alignment system test in 2002

REFERENCES

[1] http://cmsdoc.cern.ch/cms/MUON/alignment/software/COCOA

[2] http://cmsdoc.cern.ch/cms/software/ddd/www

[3] http://pool.cern.ch