COORDINATES DATABASE AT DESY

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Abstract

Since 2009 a relational database is used to store alignment data of accelerators at DESY. This includes magnets and other components together with their fiducialisation data, nominal positions of accelerator components and actual measurement data of components. Nominal alignment data for field work is produced "on the fly" by the database management system. After the alignment process the actual data is used to estimate the difference between nominal and actual lattice.

An overview of the internal table structure of the DESY coordinate database is given. The composition of the various tables into views that are suitable for everyday use is shown, as well as the database technology used for the adjustment of small measurement data sets.

INTRODUCTION

Starting with the construction of Tesla Test Facility (TTF) in 1995 magnets and other components are fiducialised individually at DESY. For TTF and TTF II with ~50, resp. ~150 components, it was still possible to keep the data by hand in ASCII and Excel files. But during this period it became clear that for PETRA III with ~1000 components this solution would not be sufficient.

Consequently, a relational database application was built, based on the central Oracle Database Service maintained by the DESY IT department. Test data was taken from the TTF and TTF II data sets, the database application was first put into operation during the reconstruction phase of PETRA in 2009.

DATABASE

The main information kept in the Database is of three different types:

1. Information about accelerator components, e.g. magnets, mirror chambers, accelerator modules, etc., including fiducialisation data
2. Information about the accelerator layout (lattice), together with centre coordinates and orientation of each component.
3. Measured coordinates of components. This is not the raw data (angles and distances), but the pre-analysed coordinate information of each measured monument of the component.
4. Coordinates of reference points.

All this information is always stored together with entry date, creation data, name of responsible person, coordinate system, accelerator name, etc.

Accelerator Components

Within the DESY naming scheme, each component is identified by a component type and a component number – an XFEL quadrupole of type G could be named XQG 42 for example. From the database side the component is identified by a unique integer number (key). As a reference inside other database tables only this key is used, so that changes of naming or other data propagate automatically throughout the whole system.

Fiducialisation data is stored in a way that one component can have multiple fiducialisations with different time stamps. This makes it possible to analyse historic data, whenever it is requested by the user.

Accelerator Layout

Information about the accelerator layout is stored in a form similar to the lattice information created by the accelerator physicists. Each installation location for a component is represented by a 6D-coordinate, given by a 3D-coordinate, normally representing the centre coordinate, and three rotation angles. Each 6D-coordinate has an individual time stamp, so that historical machine layouts stay intact over time.

Measurement data

Measured coordinates of monuments of components are also stored in the database. While from the geodetic point of view it would be best to store the original measurement data, mostly angles and distances of laser tracker measurements, it was decided to use a more practical approach. Only pre-evaluated data is written to the database, because there is often engineering and on-site knowledge involved in the evaluation process. It would be difficult to store this knowledge in the database, but lack of this knowledge would make the original data mostly useless later on.

Storing the pre-evaluated data is a good compromise between storing the original data and storing only final positions of components, because it is still possible to analyse measurement data to a certain extent later on.

As most corrector magnets are fiducialised with only two monuments and one additional tilt measurement, it is also possible to store tilt measurements in the database.

Reference points

Coordinates of reference points are stored together with time stamps so that historical data of all networks is available on request. This can be used for simple deformation analysis as well as error analysis of measurements.

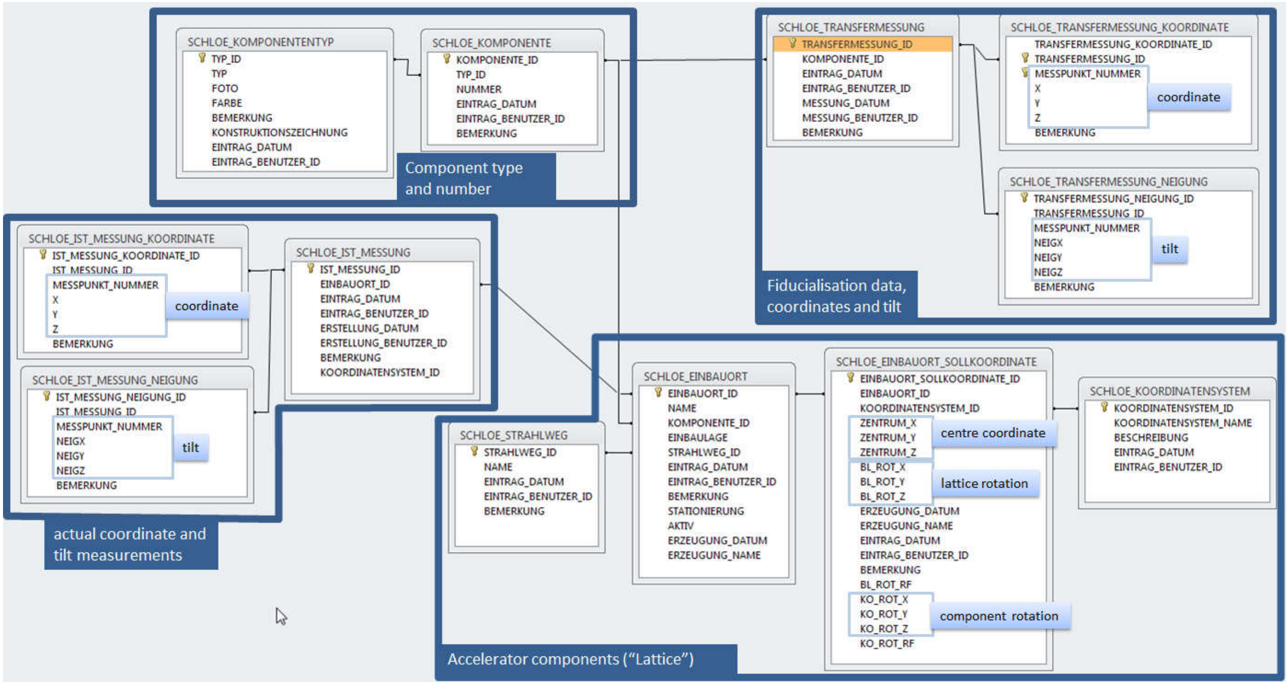

Figure 1: Table structure for the main parts of the DESY coordinate database.

DATABASE STRUCTURE

The main database structure is shown in Figure 1. For better readability tables not important for the structure itself, like coordinate systems, accelerator names, user names, etc. have been omitted.

MATHEMATICS

With PL/SQL [1] (Procedural Language / Structured Query Language) ORACLE provides a powerful extension of the standard SQL. PL/SQL contains all the functionality contained in procedural programming languages like C or BASIC. It is not, however, an object oriented programming language like C++, C# or JAVA.

Since the logical structure needed for coordinate calculations is simple, a procedural programming language is sufficient for all tasks needed in the coordinate database.

ORACLE also provides a package called "UTL_NLA" [1]. This package contains a subset of the BLAS [5] (Basic Linear Algebra Subprograms) and LAPACK [6] (Linear Algebra PACKage) routines. All the relevant routines for coordinate transformation and adjustment calculations are included, like vector and matrix addition, subtraction and multiplication (BLAS_GEMM), as well as routines to solve linear equation systems, like LAPACK_GELS [1][5][6].

To have a maximum compatibility across versions, it was decided to do all the mathematical operations inside the DBMS, only final results are exported. Because ORACLE guarantees backward compatibility across versions, only one minor modification of the code was needed since it was put in operation in 2009 (see below).

If the position of component fiducials in a tunnel coordinate system is requested (normally for the alignment of components), the 6D centre position of the component together with the fiducialisation data is used to generate the results "on-the-fly". This operation is done by a database view and involves some matrix-calculation by UTL_NLA to perform the necessary rotations and shifts.

Whenever positions of components in the tunnel are requested (e.g. by a machine physicist) the measured coordinates of fiducials together with tilt measurements (if applicable) are fed to an adjustment function that generates the actual 6D centre coordinate of this component "on-the-fly". The result is again presented by a database view as shown in table 1. Since this function performs a complete adjustment for each single component, which involves the solution of a linear equation system each time, it is time consuming.

DATA TRANSFER

Measured data is imported directly from Spatial Analyzer (SA) to the database. SA has an ODBC_PUT function that enables a measurement plan to write any data to a database.

Putting fiducialisation data is done in a similar way: After evaluation of the measurements inside SA the final data is put directly to the DB by a measurement plan.

Reading tunnel coordinates from the database to SA could also be done in a similar way, but because the ODBC_GET function of SA is slow, the tunnel coordinates are exported to an ASCII file which is then read in by SA.

Table 1: Example of actual deviations of accelerator components from their nominal position

Component	Station	Nominals date	vX [mm]	vY [mm]	vZ [mm]	vrotX [mrad]	xrotY [mrad]	vrotZ [mrad]	Actuals Date
MIAC.714.L3	691315	14.07.2016	0.0	0.2	-0.1	0.5	0.0	0.0	15.09.2016
MIAC.726.L3	703306	14.07.2016	-0.2	0.2	0.0	0.5	0.0	0.0	15.09.2016
MIAC.738.L3	715298	14.07.2016	0.0	0.3	0.0	0.5	0.0	0.0	14.09.2016
MIAC.750.L3	727290	14.07.2016	0.0	0.3	0.1	0.2	0.0	0.0	14.09.2016
MIAC.762.L3	739281	14.07.2016	0.2	0.1	0.1	0.2	0.0	0.0	14.09.2016
CSC.769.L3	746566	14.07.2016	0.7	1.1	0.3	0.9	-0.1	-0.1	14.09.2016

HARDWARE, BACKEND AND RUNTIME

The DESY central database instance is running on a cluster of 4 SunFire 4270, 90GB RAM, 8 Intel Xeon CPU X5570 with 2.93GHz, Infiniband Inter-Connect and NetApp Storage, the operating system is Oracle Enterprise Linux x86_64. [3]

For each interactive session a dedicated server process is created and thus runs on exactly one CPU core. The connected database processes, however, run on several CPUs. [4]

The cluster is hosting several databases, the alignment database is only one of them and shares the capacity with other applications. [4]

Writing data by hand to the database or requesting some coordinate sets from the database is done instantly, without any noticeable delay for the user.

Exporting all coordinates of all components involves two complete 3D rotations of the fiducialisation data of each component and thus is cost intensive. Depending on the load of the DBMS and the availability of data in the cache it takes approximately 4s to perform this task for the complete XFEL.

Calculating the actual deviation from nominal for all components is even more cost intensive, because it is done by solving a linear equation system for each component. Three Matrix multiplications with BLAS_GEMM, one Matrix Inversion with LAPACK_GELS and one matrix decomposition to gain the Eigenvalues (LAPACK_GEEV) are needed. Table 2 gives an overview of the typical runtime of the two most cost-intensive tasks.

The database software of the central DESY instance has been upgraded from ORACLE 10 to 11.2 in 2011 and from 11.2 to 12 in 2015. With the update from 11.2 to 12 a mistake in the call syntax of the BLAS_GEMM function has been corrected. This has been the only time when the alignment database code had to be serviced during the lifetime of the database.

Table 2: Cost of database tasks

Task	Runtime [s]	Average [s]
Export tunnel coordinates of all XFEL components	5.1	
	4.2	
	4.1	
	4.0	
	4.3	4.3
Export deviations between nominal and actual positions of all XFEL components	43.5	
	40.8	
	39.5	
	39.8	
	38.8	40.5

SUMMARY

The database concept shown is flexible enough to hold the relevant alignment data of all accelerators at DESY. There is no restriction in shape or size of the accelerator or number of components used. Using the central ORACLE database service of the DESY IT department makes the solution low-maintenance.

The database is able to read in the Lattice created by the machine physicists. Moreover it can produce a table of actual deviations to the nominal positions and orientations of each component in their own coordinate system, without the need of external calculation software.

A Web-Interface, based on ORACLE APEX, is planned for the future.

REFERENCES

[1] ORACLE Database Documentation; https://docs.oracle.com/en/database/.

[2] H. Pelzer et.al., *Geodätische Netze in Landes- und Ingenieurvermessung II*, (Stuttgart: Wittwer, 1985).

[3] H. Falkenberg, C. Apfel, Oracle@DESY, unpublished

[4] H. Falkenberg, C. Apfel, private communication, 2016

[5] BLAS reference, http://www.netlib.org/blas/.

[6] LAPACK reference, http://www.netlib.org/lapack/.