A 3D Spatial Information System for The Full-Scale Emplacement Experiment

A database taken to a new dimension

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Nagra's Full-Scale Emplacement (FE) Experiment at the Mont Terri rock laboratory is a 1:1 scale in-situ experiment for demonstrating the feasibility of the Swiss repository concept for disposal of spent nuclear fuel and high level waste using multiple heaters in the clay-rich 'Opalinus Clay' formation and to investigate Thermal-Hydraulic-Mechanical (THM) behavior in the Engineering Barrier System (EBS) and host rock (*Muller et al.*, 2017 SJGS). The 2.7m (diameter inside shotcrete) x50m tunnel and surrounding host rock are instrumented with numerous sensors, fiber optic cables and monitoring boreholes. Approximately 0.5 billion measurements have already been acquired. More than 1 million new measurements are acquired daily. Monitoring the subsequent heating and saturation of the EBS will continue for at least 15 years.

Normally the vast amounts of monitoring data would typically be stored in a standard information database. We have taken the FE Information System (FEIS) to a new dimension by spatially representing the experiment in a virtual 3D space. The FEIS uses the open source object relational PostgreSQL database with PostGIS and statistical R language extensions. The user friendly custom spatial operators were written cleanly using the power of PostgreSQL with advanced features like operator overloading (these operations cannot be done so easily in other databases. This database concept models the complete experiment in 3D space, uses geometric objects and custom operators which use linear algebra to work with the data and calculate spatial relationships between objects. This separates the FEIS from conventional Graphical Information System (GIS) database systems which are primarily based on mapped data. Figure 1 shows the concept of the FEIS spatial 3D model. Determining spatial relationships using a standard information database would involve complex mathematics and complex database queries. The FEIS project 3D model and custom spatial operators allow simple database queries which also help to avoid errors. There is no need to store information like "sensor A is in borehole B" in the FEIS. Instead the FEIS simply calculates that sensor A is within borehole B. This makes the FEIS very dynamic. When there is a change in the project (for example a sensor is moved) only the sensor coordinates need to be updated. The FEIS calculates all spatial relationships at run time (on the fly). As a result, data in tables, plots, calculations and even drawings are automatically updated.

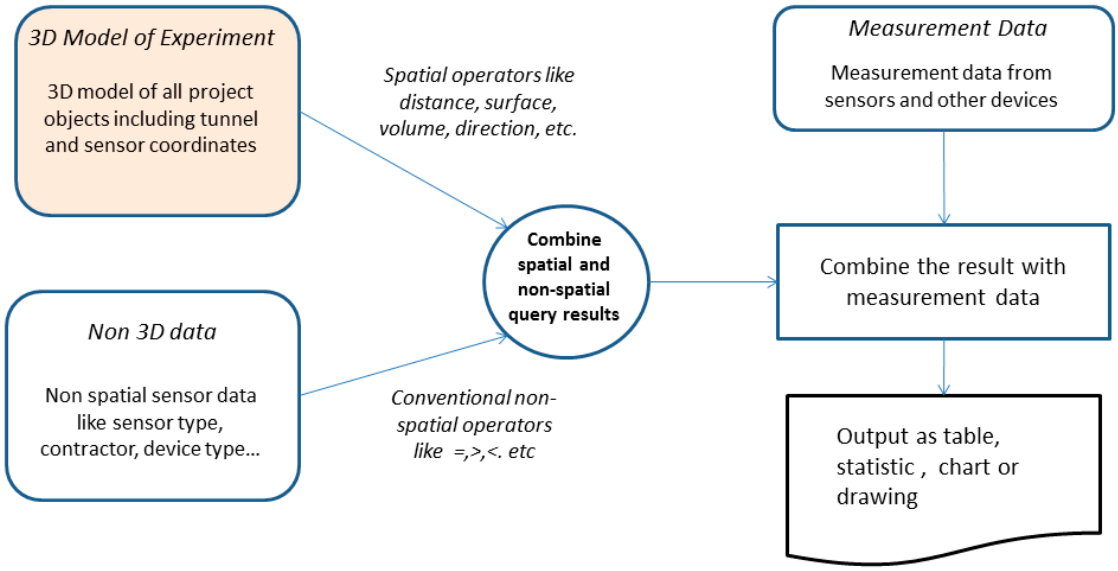

Figure 1: The 3D model of the experiment with custom spatial operators enables powerful sensor selections such as “Select all temperature sensors between 1m and 2m from the surface of heater 1” without explicit knowledge of heater position, dimensions and related mathematical formulas.

FEIS Data Pipeline

The FEIS “Data Pipeline” automatically acquires data from nine contractor sites. The numerous data acquisition systems have a wide range of formats. Data transfers to Nagra’s server are made by FTP over the Internet 24x7x365. The status and log files can be viewed from the FEIS.

Measurements are verified, uncommon sensor evolution and spurious data as well as measurements outside given limits are flagged in the associated metadata. Failure related to the instrumentation or the heating system is checked. If alarms are tripped, emails and/or SMS are sent. The flagged data are appended to the database within minutes of downloading and available for viewing and evaluation.

Data taken at irregular intervals with varying number of parameters (e.g. chemistry sample analyses) can be manually entered via FEIS entry forms.

The FEIS experience

The FEIS is a single page Internet browser application providing easy, fast and efficient review, analysis and reporting with the feel of a desktop program.

Charts are interactive and provide a fast fluid user experience. Modifications of the charts (scales, line types, colors, etc.) can be easily done. Tables (data listing) are fast and dynamic. Table columns can be sorted from high to low (or vice versa) and hidden when not of interest (Figure 2).

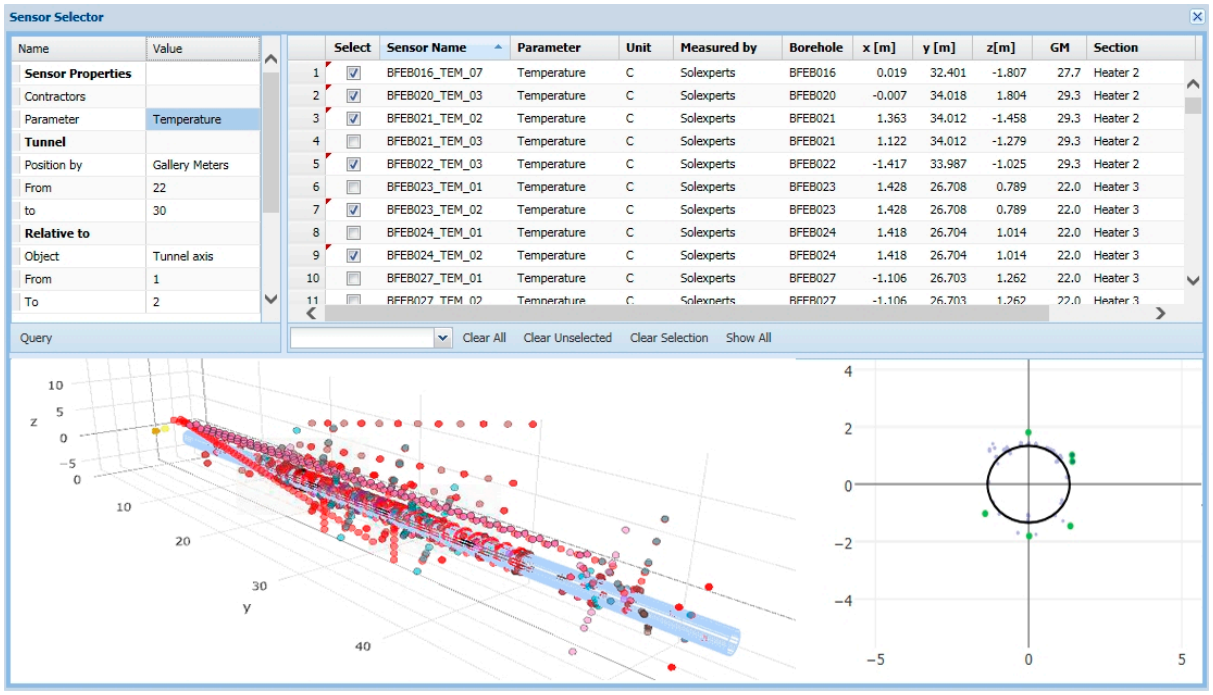

Figure 2: Sensor selection windows showing spatial and non-spatial selection fields and the sensor selection table with sortable columns.

Users can define mathematical expressions (calculations, functions and statistics) using sensor measurements as variables. The expression can be used to evaluate possible relationships between measurements (e.g. average of temperature sensor 1 and 2 gives an estimate of the temperature in the middle point of the 2 sensors) and more. Expressions can be saved, plotted and evaluated along with other measurement and modelling data.

The FEIS also includes documents and provides complex and complete text search functionality with keyword and full text (Google like) searches which are independent of grammatical structure. The system automatically extracts keywords from the document text. Photos, videos and spreadsheets can also be added to the system. Search results are ranked by the significance (likelihood) that the document contains the desired information.

For public access by registered users over the Internet, a Public replicated database (a subset of the main database which does not contain personal data or confidential reports) is installed on an external server.

Summary

The FEIS is an Internet web browser program that works like a desktop program. The system currently has 0.5 billion measurements and thousands of documents. It offers investigators an easy-to-use, quick and powerful tool for data review, evaluation and analysis.

Topic 7: Temperature-induced effects (THM coupled processes)
OR
Topic 10: Monitoring (from initial state to post-closure)
Oral presentation