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GEOSYS: AN X/MOTIF-BASED SYSTEM FOR ANALYSIS AND MANAGEMENT OF GEOTHERMAL DATA

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ABSTRACT

The Geothermal Data Management System (GEOSYS) has been developed to allow storage, retrieval, and analysis of the large volume of data associated with a geothermal reservoir, including well drilling data, well log data, production (chemical and flow) data, and geographical data. The system allows the user to display overlays of well locations, faults, and surface features on maps or topographic images. Subsurface cross-sections can be displayed by selecting any two points on the map. Cross sections show subsurface topography together with the projections of wells along the cross section. The structure of each individual well can also be displayed in detail. Downhole well logs can be selected, displayed, and expanded to arbitrary scale. Time histories of production data can be displayed for the field and for each well. Data from the Cerro Prieto geothermal field has been used for development and testing of the system.

This type of system has been made possible by recent advances in hardware and software technology, and the dramatic reduction in cost of high speed workstations and disk storage. GEOSYS was developed using the X Window System and the OSF/Motif widget set. The X Window System was designed specifically to provide hardware independence for interactive systems based on bit-mapped graphics with a Graphical User Interface (GUI). Systems developed using X run on most modern workstations, and can run across a network with the application being resident on only one computer, but accessible to all others.

INTRODUCTION

The exploration, testing, development, and operation of geothermal reservoirs generates a great quantity and variety of data. Geothermal reservoir analysis and assessment require access to these data in ways that are often difficult to predict. The purpose of the Geothermal Data Management System described in this paper is to provide access to all of the data that are collected related to a particular geothermal reservoir, and to allow interactive extraction and display of these data in a wide variety of formats. The development of modern high speed workstations, and advances in both hardware and software design have made it possible to develop a system with much more extensive capabilities than have been feasible in the past.

GEOTHERMAL DATA MANAGEMENT SYSTEM– CONCEPTUAL DESIGN

The Geothermal Data Management System is an example of a general class of system built on four basic elements: data, analysis tools, a relational database, and a graphical user interface. In this case the data include well log data (e.g. pressure, temperature, and spinner); related well data such as well locations, deviation logs, and drilling logs; historical data such as production and well test histories, and physical data such as topography and fault locations. The analysis tools operate on this data and extract and/or display information. Examples of analysis tools are programs to display well logs and time histories, and to overlay event and geographic information on maps and images. The data are maintained within a relational database system. The database structure is designed to allow virtually any type of data to be stored and accessed within the system. The relational database performs the function of keeping track of raw data and related information, and keeps track of any changes to the database. The graphical user interface (GUI) allows the user to interact with the data, database, and analysis tools. All user interaction takes place through the graphical user interface. The GUI is designed to minimize the amount of keyboard entry and to allow most selections to occur though mouse driven menus and displays.

GEOSYS consists of a hierarchy of programs: a master program and a set of analysis modules which may in turn start additional modules. At the top level is the master program whose primary function is to start the other analysis programs. This top level program allows the user to obtain a summary of available data, to select the geothermal field to be processed in analysis modules, and to select analysis tools to apply to the data. By design, the master program is both small and simple. Because of this, it is easy to expand the program to add additional analysis modules as required.

SYSTEM REQUIREMENTS

The graphical user interface is based on the X Window System (X11, currently in revision 5, refs: Scheifler and Gettys, 1990; O'Reilly, 1988). X is a client/server windowing system that was designed specifically to allow hardware independence and transportability of applications across different hardware platforms. GEOSYS is being designed and implemented on a Sun workstation, however because the interface is based on X, transfer to any other system that supports X and Unix could easily be accomplished. Also, because X is a client/server system, GEOSYS can run on one computer (the client) while the display and all interaction with GEOSYS occurs on a different computer (the server).

GEOSYS has been written in the C and FORTRAN programming languages. C is required because calls to Xlib (the X Window System interface) are in C, and because C is better suited to the design of complex systems with a variety of data structures than FORTRAN. FORTRAN is being used because it is better suited to certain types of computational analysis than C. As a result, the top level programs, interactive modules, database interface, and graphics routines are written in C, and when necessary these routines call FORTRAN subroutines and start executable FORTRAN programs.

The X interface is being written using the X toolkit (Asente and Swick, 1990; Young, 1990). The X toolkit enforces an object-oriented approach to programming by combining the windows and the operations on the windows into "widgets". GEOSYS uses the Motif widget set developed by the Open Software Foundation (OSF, 1990) and some additional special purpose widgets.

The relational database tables used in GEOSYS are independent of the particular relational database management system used for accessing the tables. Currently, GEOSYS is being developed using an internal database manager that accesses the tables as required by the system. All database tables are documented in a standard format before being created or used within the system. All files required for defining the database structure in SQL, as well as internal data structures used within the GEOSYS system are generated directly from this documentation. This way typographic errors are avoided and any changes in the database structure can be made throughout the system by changing only the documentation and regenerating dependent files.

SYSTEM COMPONENTS

The Geothermal Data Management system currently consists of 7 modules:

GEOSYS

This is the master program to select data and execute other modules. This and all of the other modules contain on-line help to aid the user in understanding the options available for each module.

Map

The Map module allows display of a background image which may be an aerial or satellite photograph, a color or grayscale representation of topography, an image displaying a subsurface parameter (e.g. temperature at a given depth), or any other geographic image. Other information may be overlaid on top of this image. Some types of overlays include well locations, hot spring locations, faults, topographic contours, roads, towns, and other surface or subsurface features. Wells can be selected by pointing at any well on the Map. Any of the other GEOSYS modules can then be started using the selected well. The Cross Section module can be started by selecting any two points with the mouse.

Cross Section

The Cross Section module displays the topography, subsurface geology, and the projection of each well along the selected cross section. This module is normally started from the Map module, although it can be started directly from GEOSYS to display a cross section through a selected well.

Well

The Well module shows the structure of each well in detail, including well deviations along North-South, East-West, and vertical projections, hole/casing structure, cemented and slotted regions, circulation loss points, surface elevation, and stratigraphic layers along the well. Additional information about the well can be displayed in tabular form.

Well Log

The Well Log module is used to display subsurface profiles of temperature, pressure, spinner, and other downhole measurements. The displays can be expanded to show fine details of the profiles by simply drawing a rectangle with the mouse around the region to be expanded. Well logs can be displayed as a function of measured depth, true depth, or elevation. The well structure, hole/casing size and locations of circulation loss points can be displayed together with the profiles, and automatically rescale when a region is expanded.

Production

The Production module allows production data taken over the history of the field and individually for each well to be accessed, displayed, and correlated. Any type of production data including mass flow rate, enthalpy, temperature, and chemical measurements can be stored and accessed by this module. The Cerro Prieto production database used to test the system contains over 120,000 measurements taken from 200 wells over a period of 25 years.

Database

The Database module is the link to the relational database that allows data to be entered, changed, and removed from GEOSYS. Forms are provided for data entry and review for each of the 24 database tables, however data may also be added by reading from a file in a format that mimics interactive entry. This can be a very significant convenience when a large amount of data is to be added to the system. Data added by file can then be reviewed, edited, and corrected interactively.

CONCLUSIONS

The development of systems such as GEOSYS has been made both necessary and feasible for three reasons:

1. The volume of data associated with a geothermal field and used in reservoir assessment has been rapidly increasing. This volume of data has great benefits in the ability to analyze a field, but is difficult to analyze by traditional means.
2. Over the last few years, the cost of high speed workstations and disk storage has decreased dramatically, while the computational speed and storage capacity have simultaneously increased dramatically. The capabilities of these systems make it possible to develop interactive systems that access and analyze large volumes of data.
3. The development of the X Window system has made it possible to develop sophisticated systems with a transportable Graphical User Interface capable of operating on machines from a wide variety of vendors and on different types of machines across a network. Because of this, the software no longer is restricted to a particular brand of hardware, and can be easily transported to different machines as hardware technology improves.

As a result, it is now possible to maintain nearly all of the data associated with a geothermal field on a workstation, and to provide the capability to access and analyze this data. GEOSYS has been developed for this purpose.

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