

The Real Meaning of Geoscience Data and Process Integration

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Abstract

In the last two decades, geographic information systems (GIS) have proved to be a promising technology for integration, management, analysis and visualization of diverse geoscientific data. In spite of this success, GIS cannot offer a comprehensive set of tools for all types of geoscientific problems, therefore specialized software applications are required for each problem domain. Geoscientific methods, dealing with these problems, keep on changing with the advancements in technology. Thus it is difficult to manage and maintain one large system with a whole set of tools and functionality. The solution to this problem is a front-end GIS linking an array of geoscience databases and their specialized software applications. This paper presents an expandable architecture in which the GIS acts as a top level interface to interactively access multiple databases and activate their related processing and visualization applications. This architecture is used to integrate various petroleum industry related exploration data layers and their concerned software applications. The effectiveness of this system is demonstrated through some practical examples.

Introduction

Historically geographic information systems (GIS) have long been used as an integration tool for raster and vector data in a number of applications (Mattikalli et al., 1995). They have provided efficient georeferenced data management solutions by incorporating relational database-management systems (RDBMS) for spatial indexing of data (Batty, 1992). Similarly artificial intelligence (AI) techniques have been used to enhance the capabilities of a GIS in handling large, diverse geoscience databases (Albert, 1988). GIS has also been integrated with visualization tools to generate complex graphical representation of the retrieved numerical data (Rhyne, 1997). More recently web-based technologies (Fried, 2000, Ibrahim et al., 2008) and Google Earth (Thurmond et al., 2008 and Chen et al., 2009) are being used for easy access, interaction and 3D visualization of spatial data.

Parallel to the above mentioned advancements, geoscientific data is becoming increasingly complex and challenging. It is diverse, voluminous and exists on heterogeneous platforms in a variety of formats. In

contrast, a given set of geoscientific analysis requires different types of datasets to be geospatially linked and integrated for extensive processing and visualization by multiple specialized software applications. There are practical issues related to mining and extraction of datasets from different sources, their transformation into a common geodetic reference system, loading of data into multiple applications and finally integration of results for visualization.

Keeping in view such requirements, a computational environment is presented which integrates geoscientific data and software applications under a centralized geographic information system (GIS). The system provides an open framework to declare new data types as data objects into a spatial object oriented relational database management system and define interactive actions linked with queries for retrieval of data from the database. Applications can then be registered as processes operating on these data types. Similarly format filters, for the data import export layer, are also registered to access and deliver a data type in different formats. In this way the presented system acts as a GIS based interface for interactive retrieval, processing and integrated visualization of multiple types of geoscientific datasets.

Data Definition and Applications Registry

The presented system has been developed as an interactive front-end over the vast geoscience data resources and software applications developed under the framework of integrated geo systems (IGS) (Khan, 2000). Due to the open and expandable design of this system, all data and software components need to be defined and registered under its framework. This definition procedure must be followed for each data type.

Major steps involved in complete definition and registry of a data type and its related software applications are summarized below.

- The system considers each data type as a data object, thus its definition consists of a data object model which includes the complete structure of its relational tables in the database. Each data object represents a data layer on the GIS.

- The database model requires all data objects to have a geospatial location, thus each dataset needs to be georeferenced before storage.
- Definition of interactive visual action that can be performed over a data layer. This includes clickable graphical objects on the GIS as well as click and drag to select a geographic area of interest for data extraction.
- The visual actions trigger events to execute queries which have been written in the form of Structured Query Language (SQL). These events also pass parameters from the GIS interface to the SQL such as data object name or geographic area limits over which the data is searched and extracted.
- Registration of applications as methods that can operate on the retrieved data. Each data type can have multiple applications registered as editing, processing or visualization tools. This application registration is linked with a visual action and its subsequent query. In this way a visual action after successful retrieval of data from the database activates an application to operate over this data. In case of multiple application linked with a single visual action a pop-up menu is displayed to select the appropriate application.
- Optionally data formatting filters for import/export of a data type to/from third party applications are also registered. These filters are activated whenever data needs to be transferred to such applications.

By following the above mentioned steps, a data type can be completely registered along with its concerned applications. These steps must be followed for registration of each data type. Once multiple data types have been successfully registered and their corresponding data is loaded, the system can be used as a single integrated data management, processing and visualization interface.

This working of this system is illustrated in Figure 1. The GIS acts as front-end desktop, where interactive visual actions are translated into events along with parameters picked from the interface. These events execute queries to retrieve data from the database and then activate applications as methods for processing and visualization of this data. In case of multiple methods, available for a data type, a menu for selecting the desired application is displayed. The system also provides integrated visualization of retrieved data types or their processed results as separate overlying data layers on the GIS. It can also be used, along with specialized applications, as an interactive survey planning and designing tool. In this way the system provides an open and flexible environment that can be extended to incorporate new data types and adopt the changing trends in technology and data standards.

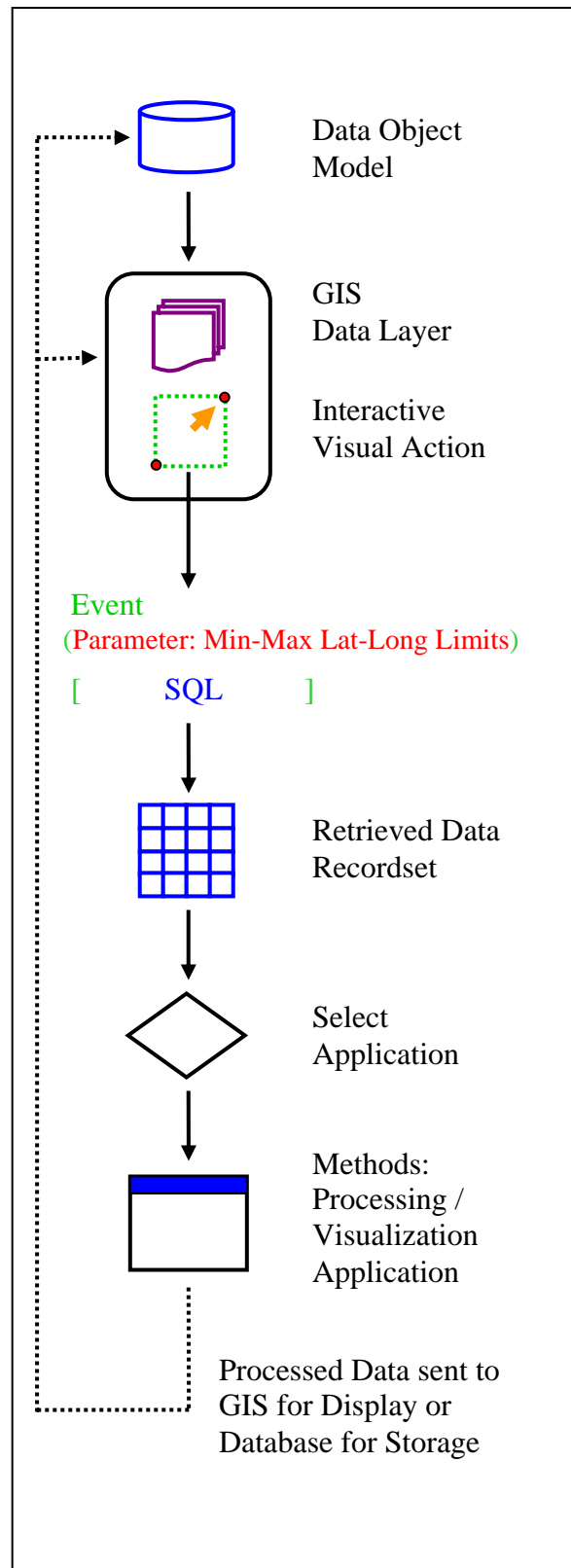


Fig. 1. The complete processing workflow of the system, starting with the data object model definition, which is represented as a data layer on GIS. Interactive action triggers SQL event to retrieve data and calls methods to execute processing or visualization applications.

Integration of Data Layers

The system is used to integrate various spatial data layers and georeferenced data for Pakistan. A list of these data layers is summarized below.

- Multi-resolution satellite imagery tiles (Khan et al., 2008)
- Digital elevation models (DEM)
- Cultural Information
 - Administrative Boundaries: International, Provincial and District boundaries
 - Cities
 - Rivers
 - Roads Network: Digitized as well as GPS mapped roads
- Exploration and Production Data
 - Lease concessions boundaries and their related corporate information

- Wells coordinates, formation tops, petrophysical logs and production data
- Seismic Data, observer reports, statics, velocities, interpreted horizons and faults
- Gravity Data
- Geological maps and cross-sections
- Seismology and Tectonics Data
 - Major Tectonic Faults
 - Seismicity Maps
 - Earthquake Epicenter Data

The system is used to interactively and efficiently extract and interrelate data from the above listed data layers, send it to applications for editing, processing analysis or visualization. Figure 2 illustrates the extraction and processing of well related data by simply clicking a well on the GIS. Similarly Figure 3 shows a top level multi layer GIS front-end which is used to interactively select an area of interest for

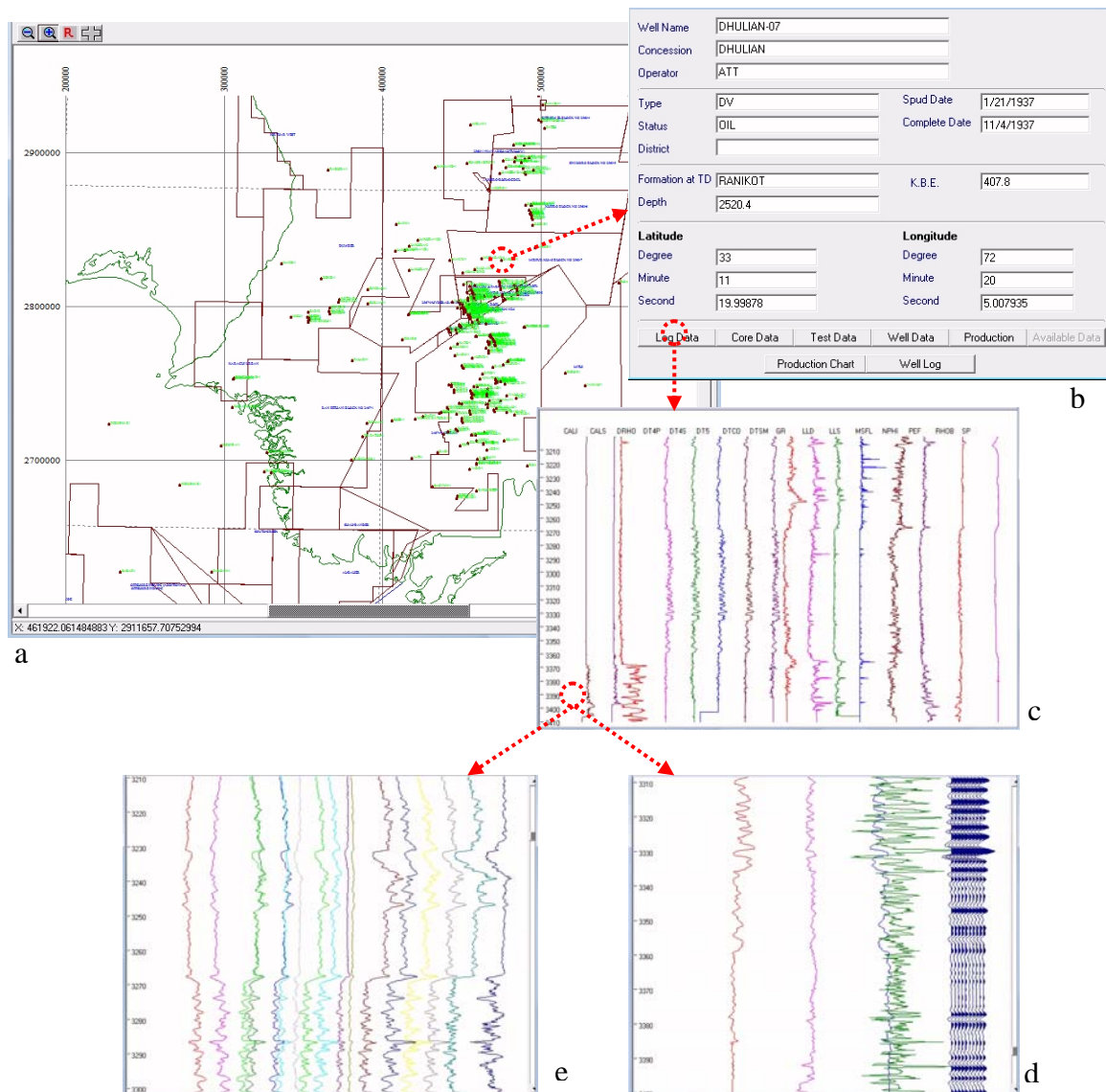


Fig. 2. (a) GIS Front-end with wells and other data layers. A well is clicked and its basic information (b) is retrieved from the database. Further petrophysical logs (c) are extracted and sent to processing applications to generate synthetic seismogram (d) and engineering properties logs (e).

extracting the digital elevation model of the area along with seismic lines and their related datasets. These examples demonstrate the effectiveness of the GIS interface, which is used to dig down information related to a data object.

Conclusions

A GIS based front-end is presented which provides seamless integration and expeditious delivery of spatial data and information through a single user interface. The major advantage of this system is its

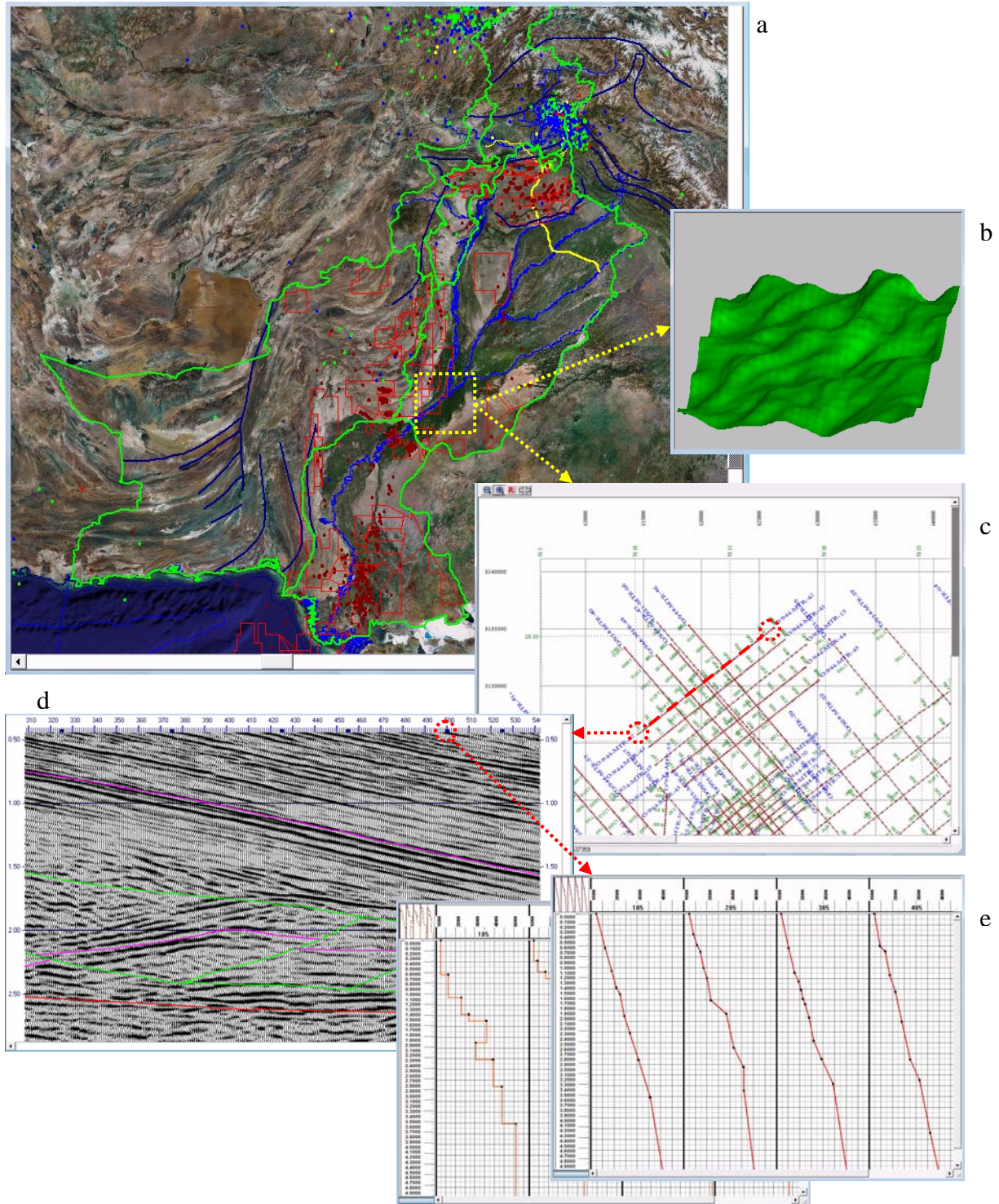


Fig. 3. (a) Top level GIS Front-end displaying multiple data layers. An area of interest is interactively selected over this front-end to get digital elevation model (b) and detailed seismic base map (c). A line is clicked on the base map to get its interpreted seismic section (d). On the seismic section common depth point (CDP) locations are selected to get their velocity functions (e).

expandability through an open framework in which new data layers can be defined and their corresponding interactive queries, processing and visualization applications and data format filters can be registered.

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