# Issues In Interacting With GIS In Hydrocarbon Exploration Industry

Muhammad Shaheen [1], Muhammad Shahbaz [2], Zahoor ur Rehman [3], M. Sarshar Aurangzeb[4]

[1,2,3.] University of Engineering & Technology Lahore, Punjab Pakistan
[4] Pakistan Accumulators Pvt. Ltd. Pakistan
[1] shaheen@uet.edu.pk, [2] m.shahbaz@uet.edu.pk, [3] xahoor@gmail.com, [4] sarshar_zeb@yahoo.com

**Abstract:** Technology changed the scenarios in past few decades. Recent developments in the processing power and storage capacity revolutionized the industrial development and even troubleshooting. There was a time when basic computational tools were very slow or even unavailable in industry but now state of the art tools and technologies can envisage exploring virtual reality. In energy sector, world is desperately looking for large reserves of fossil fuels along with other reserves. The efforts in hydrocarbon discovery phase deplete lots of resources resulting in either a very small sized reservoir or in failure. Geographic information system (GIS) along with related technology of remotely sensed satellite images, information system skeleton, graphical user interfaces (GUIs) and analytical tools can also be used for automated hydrocarbon explorations. GIS is operated by GIS analysts who have specialized skills in geo-spatial technologies. Therefore the exploration companies especially in the developing countries of the world do not rely on the capabilities of GIS and remote sensing. The reasons are concluded to be. (1). Interface of GIS is not friendly for non-specialist and/or novice user. (2). Accuracy of spatial data is not convincing for accuracy-critical tasks. (3). Unavailability of standards of spatial / non-spatial data display. The paper addresses the issues in interacting with GIS for hydrocarbon exploration and proposes enhanced model of Geographic Information System (GIS) for making it a reliable technology in any part of the world in hydrocarbon discovery phase. [Journal of American Science 2010;6(7):262-271]. (ISSN: 1545-1003).

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## 1. Introduction

Technology has allowed an incredible increase in the success rate of discovering various sources of energy. Oil and natural gas are and will remain major energy sources in most part of this century. There are some big reserves of natural gas in Asian region which made the countries to sustain balance between exploration rate and consumed resources. Beneath earth's surface the accumulation of this treasure is a gift of nature and over the surface, experts are the source to detect and explore it. A lot of resources are consumed in exploration phase resulting in either a big reservoir or inadequate prediction.

Hydrocarbon exploration passes through subsequent phases starting from lead identification to discovery and finally feeding the reserve to production plant (McLay et.al. 2003). Remote sensing and GIS can contribute with all its potentials not only in geological mapping but also for analytical purposes and interpretation of geological data for making hydrocarbon explorations accurate and cost-effective (Everett et.al. 2002). Geographical Information Systems do also have significant contributions in developing risk simulation models on spatial data for diverse class of systems (Thumerer et.al. 2000; Fuest et.al. 1998; Chang et.al. 1997; Lovett and Parfitt, 1996; Emmi and Horton, 1995; De silva et.al. 1993; Goodchild et.al. 1993; Vanvoris et.al. 1993). These systems can help making reconnaissance maps, spud date maps, operator maps, geological structure map and production maps etc to support hydrocarbon exploration. The systems are also effective for spatial correlations, statistical analysis, identification of changes in features marked at remotely sensed image due to the presence of hydrocarbons and spatial analysis (Barrel, 2000). The launch of IKONOS satellite in 1999 enabled the world to get updated, small and compact satellite images every day. Steve Adam (Adam, 2000) recommended the use of IRS-1 satellite imagery for positioning and classification of structures in low/moderate density environments and IKONOS's imagery to take digital ortho-photos in high density environments. The advances in Global Positioning Systems (GPS) contributed a lot in accuracy-critical tasks. A GIS data collection project can now be completed with the help of PDAs and assistant software (Wadwani, 2000).

Geo-technology made geo-spatial data mapping a powerful tool and geo-analysis more intelligent. In oil and gas exploration scenario it is used to characterize and analyze reservoirs (Walters et.al. 1996), characterize isotopic data (Neilson et.al.

1995), seismic and geological data (Neilson and Nash, 1997) and Lineament data (Warner, 2000). Nash and Adams (2001) used GIS to enhance tracer analysis by incorporating GIS functions in different sort of interfaces. The use of GIS in natural resource industry is discussed by various researchers including Ramdan et.al (2009; 1999), Williams (2000), Porter et.al (2000), Shah (2003) and Iqbal (2004). Implementation of GIS is beneficial not only in exploration monitoring but also in generating self-revenue by utilizing the services of petroleum exploration data management (Shah, 2006).

In spite of the above stated facts, the use of GIS and remote sensing imagery is rare especially in developing countries. The planning departments of these countries are interested in increasing the usage of GIS and its applications in natural resource exploration but unfortunately, it is not well practiced in various explorations and planning departments.

Robert L.Labarbera (2006) in Fort Bend County US realized that GIS is not in public access as it is rarely articulated in newspaper and television. Internet, periodicals and conferences are the only sources of information of GIS. Unfortunately all the three are not regularly interacted by planning departments in third world countries. Robert also identified that Fort Bend County individuals were not knowledgeable of new technologies and trends in GIS. The company was lacking in GIS personal resources and products and there was no GIS feedback from clientele. Dutch market research reflected that municipalities have low confidence on geographic data (Kroode, 1994). This market research was made in Netherland when they were infant users of GIS. The growth level of GIS in various parts of the world (especially developing countries) is still very low. Onsrud et.al (Onsrud and Masser, 1993) argued that the initial rate of adoption of technology is slower until the volume of users increase. The increase in number of users gives rapid boom to the technology. Masser (1998) concluded that the unavailability of digital data is one of the factors for which GIS is not used commonly. Rhind (1995) pointed out the role of government in improving the diffusion of GIS. Governments in most of the countries are primary sponsor of national geodetic framework hence stands at prominent position to ensure spatial accuracy. R.Colijin (2000) surveyed about the rate of GIS adoption, GIS policies, and expectations and goals of GIS adoption.

The use of GIS in developing country is much greater than its use in developing countries of Asia (Yeh, 2004). Ibrahim Elbeltagi et.al (2005) studied the factors influencing the usage of information systems in less developed countries. He concluded from the results that Perceived Ease of Use (PEU) and Perceived Usefulness (PU) affect the use of information system. The arguments by Goodman & Green (Goodman and Green, 1992), Krovi (1993), and Lu et.al (1989) revealed that poverty, trade barriers and lack of infrastructure affect the usage of information technology. Technology Adoption Model (TAM) is one of the stronger tools applied in developed world for measuring the acceptance of technology by finding user perceptions (Boudreau et.al. 2001)**.** An organization's culture also contributes a lot in adoption and use of GIS. W.H.Erik et.al (De Man, 2002) underlined the importance of social conditions and cultural desirability in the adoption of GIS. Ian Muehlenaus (2007) identified the extents of GIS ubiquity and diffusion in various states. He concluded that considerable growth with potential in developed countries has been observed in industrial as well as non-industrial sector.

The variability and distribution of natural resources can help decision-makers to keep predicted values in mind while making decisions about future. In spite of the mentioned fact the use of GIS in which this industry is disappointing (Huizing et.al. 2002). In spite of the incorporation of geo-spatial information and presence of digital maps, managers tend to use paper maps (Kevany, 2003; Zerger and Smith, 2003; Cahan and Ball, 2002). There are certain cases when the interest of decision-maker considering various factors for an unchallengeable decision is constrained by non-integration of information, inaccessibility, incomprehensibility, lake of expertise etc (Dalal-Clayton et.al. 1993). Amira Sobeih (2005) stated that the use of GIS has neither penetrated in business community nor in user community in Egypt. The penetration is not expected until communication and participation channels are built at all levels i.e. local, regional, national and international. Only after that natural resource exploration in all its activities can exploit GIS (Sobieh, 2005).

Hydrocarbon exploration if combined with GIS utilization required analysis of satellite imagery, digital imagery, GPS surveys, surface interpretations, geological studies and infrastructure evaluation. GIS today can help to find and derive spatial relationships among environmental factors, well logs, sedimentary rock analysis and equipment installed on pipelines. The GIS is in infancy stages whereas the applications for which GIS can be utilized are mature in industry. Following this demand, the paper identified the reasons for non-exploitation of GIS and proposed model to overcome the dilemma. Guoray Cai et.al (2006) worked on effective GIS interfaces to support crisis management in the terms of immediacy, relevancy and sharing.

The hydrocarbon exploration companies do not much rely on the capabilities of GIS. This paper identifies the reasons that why GIS is not used inspite of its potential and what are the reasons prevailing behind it for not using this state of the art technology. The paper proposed a model for making certain modifications in existing GIS framework so that it becomes more usable in industry. The reasons for non-exploitation of GIS in hydrocarbon exploration are found to be:

1. The graphical interface of GIS is not friendly for non-specialist user.
2. Accuracy of spatial data is not relied in accuracy-critical tasks.
3. The standards of spatial/non-spatial attributes in GIS do not exist.

These points are elaborated one by one in the succeeding sections.

*Non-Friendly GUIs*

Mark et.al (1992) gave some generic design guidelines for GIS interface design. These include degree of agreement, smart menus, conceptual structure of program, easy to learn interfaces, direct computation and spatial data presentation. Anselin (1999) focused on visualization of spatial distribution where as Trevor et.al ( Trevor and Gaterell, 1995) suggested a design which is easy and appropriate for analytical operations. Dykes (1997) suggested including dynamic graphics and brushing for spatial exploration. He worked on making the interface design simpler so that the user working on MS-Office would be able to use it.

Technologically backward industries of developing countries find it hard to use graphical user interface of GIS. In our study, an investigative survey has been accomplished in energy companies including MOL (Marine Online), SNGPL (Sui Northern Gas Pipelines Ltd), SSGCL (Sui Southern Gas Companies Ltd), MOL and LMKR (Landmark Resources) to extract the factors causing limited or no usage of GIS in hydrocarbon exploration activities. The survey along with field visits to different companies enabled us to conclude on following enhancements in design of graphical user interface of GIS.

- The companies had been using management in formation systems, transaction processing systems and other decision support systems for a long time. They are well aware of its operational and analytical capabilities hence working on it regularly or at least periodically. The interface of GIS is quite different. The diffusion of other information systems was quick because of its compatibility with manual system in execution but GIS is not an alternate to some existing file system. For example national survey sheets are used for cartographic mapping in SNGPL. The cartography is overlaid on these sheets by using AUTOCAD. The use of AUTOCAD is still popular for such cartographic mapping whereas GIS has the capability to digitize existing networks on satellite imagery.
- The annotations used in the GIS for hydrocarbon exploration are not similar with commonly used terminologies in the company. It is very difficult for an experienced manager to work on new terminologies especially when the work is time bound and need faster performance.
- Various functions which are used for statistical analysis are facilitated in GIS but are not easy to use. These functions need specialized skills of GIS professional whereas the human mediator skills become bottleneck when quick information transfer is needed (Egenhofer, 1995). Most of the managers are not even aware of handling basic interface options so they have to depend on GIS technical persons. Technical training of GIS that is designed within the company is insufficient for exploiting esteemed capabilities of GIS.
- The companies are working on paper maps. The managers feel operational hurdles while working on satellite imagery. The configuration of both of these differs in spatial identification of points as well as in layout.

1.1.1. In the light of above discussion, a model for designing graphical user interface of GIS is designed which is presented in Figure 1. The model includes such flexibilities so that non-specialist GIS user would equally be able to use the application. *Base Map Options:* The Interface should be equipped with options to select base map. The developer can rectify the image on different base maps. When one selects the base map for GIS, the corresponding rectification would automatically be applied and the layers got adjusted.

1.1.2. *Expertise-Wise Usage:* There should be an option for the users to define its expertise. Whether the user is expert, mediator or beginner etc (The expertise will be classified according to the available human resources). Each user will be offered the interface options according to his expertise. For example an experienced user will be able to use analytical tools and play with the incorporated spatial database whereas a beginner will only be able to utilize the facilities like searching a location, printing data and displaying attributes.

1.1.3. *Wizards for GUI:* The GIS in the above mentioned companies do have graphical user interfaces on which the attribute information of various features is displayed. For example, in pipeline industry the GUIs of Town Border Stations, Cathodic Protection (CP) Stations and Sales Metering Stations (SMS) have been incorporated. These GUIs contain the attributes of above mentioned pipeline network assets like No of CP Bond Box in CP Station or no of pre-fabricated insulating joints in CP station etc. The GIS interface (ESRI's ArcGIS is most commonly used) should contain wizards to create new GUIs by selecting the fields to be included into GUI from the list provided. The user should have the option to name the fields of GUI according to his own understandings.

1.1.4. *Annotation Libraries:* The features of GUIs are annotated just like the labelling of a biological diagram. There should be an inclusion of various categories of annotation libraries including hydrocarbon exploration annotations, pipeline annotations, hazard management annotations, geological annotations, refinery annotations etc. These annotations and symbols should be finalized after consulting international organizations. For example it is necessary to consult ASME (American Standards for Mechanical Engineers) in order to finalize the annotation libraries related to oil and gas engineering. The user does have the option to select the desired annotation library before presenting GIS to the concerned manager.

1.1.5. *Division of Interface:* The interface of GIS may possibly be separated in three different frames.

(1). Information retrieval window.
(2). Information analysis window
(3). Information querying window

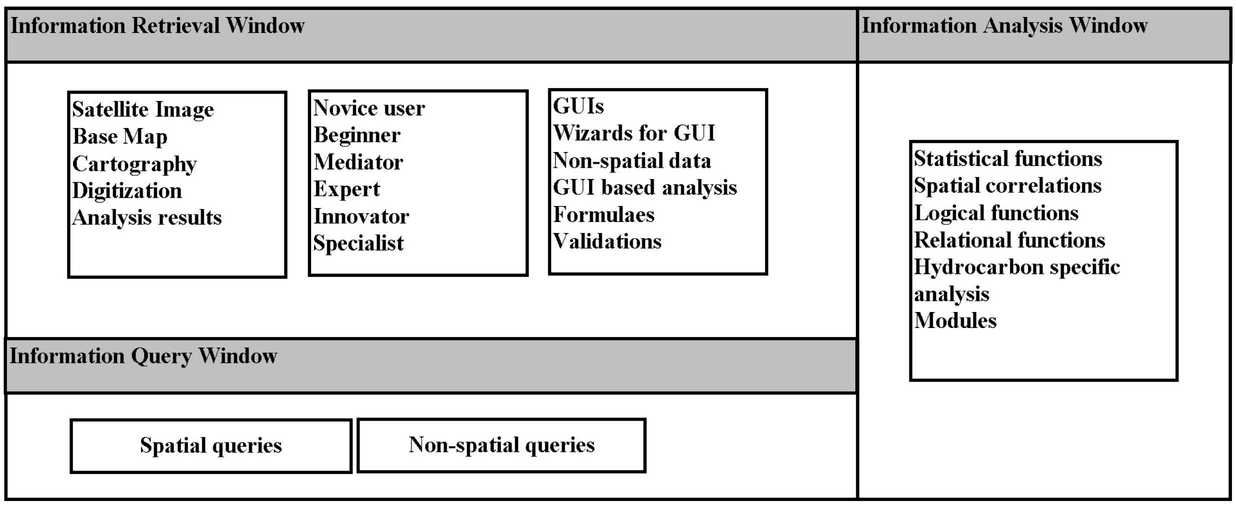


Figure 1 – Components of GIS Interface

*Unreliable accuracy in accuracy critical tasks*

The concepts of precision and accuracy in geomatic engineering are usually exemplified by standard deviations and root mean square errors (Li and Yuan, 2002). Error handling in spatial information is major research focus, which is the evidence of discrepancies, caused of inaccurate spatial information. In the applications where the accuracy is evaluated at a broader scale are excluded from the list. Li and Gao (1997) proposed quantitative analysis of error propagation in information retrieval from remotely sensed image through GIS. Spatial data is mostly obtained by three different methods. (1), Field Survey (2), Digitizing maps and (3), Remote Sensing. Xiaosheng (2005) classified errors in spatial data which is obtained by above methods. The errors which are produced in accuracy critical tasks especially in energy sector i.e. in exploration industry, pipeline industry etc.

field survey are because of error in centering, reading, errors of instruments and impact of environmental elements including atmospheric pressure, temperature and lateral refraction and climate etc (Ying, 2002). The errors in digitization are caused because of errors in maps, distortion errors and vectoring errors (Litao, 2003). Errors in remote sensing data can be isolated at each step of remote sensing procedure i.e. data collection, data processing, data analysis, data transition and artificial interpretation. The described errors are common in nature and exist in all data. The most prominent error which is specific and annoying to the companies of third world countries is positional accuracy error. The error is not affordable in

ZENG Yanwai (2007) identified paper map distortion, scanning error, image processing or geometry adjustment error, map orientation error, data acquisition error and editing error. Above all, a default error of 2-10 meters is included in GPS coordinate readings.

To avoid map positional error in particular and scanning, geometry adjustment and map distortion error in general, the interface is equipped with a back propagation artificial neural network. ZENG tested positional accuracy from coordinate difference using the formula.

$$\sigma_x = \pm\sqrt{\sum_1^n \Delta x_i^2 / n}\ ,\quad \sigma_y = \pm\sqrt{\sum_1^n \Delta y_i^2 / n}\ ,\quad \sigma_z = \pm\sqrt{\sum_1^n \Delta z_i^2 / n}$$

x,y are representing coordinate positions and h is for elevation. Δx, Δy, Δh represent coordinates differences. $\sigma_x$, $\sigma_y$ and $\sigma_z$ represent positional accuracy.

In proposed system, a backpropogation neural network (BPNN) is trained on positional accuracy values extracted by above equations. The BPNN will validate the positions which lie within the range of acceptable values. Similarly the same network is trained on map distortion acceptable range and geometry adjustment error. BPNN is multi layered network with number of hidden layers. The learning stages contain two phases. (1). Forward Pass (2). Backward Pass shown in equation 3 and 4 (Trappey et.al. 2005)

In Equation 1 $W_{ij}$ is the weight connected with input layer. $X_i$ is the positional accuracy. NI represents net input. In Equation 2 $W_{jk}$ is the weight connected with different hidden layers and $H_j$ represents particular hidden layer number.

The forward pass calculates net input of every node to generate output using activation function. The net input from input layer to the hidden layer and output at output layer is calculated in the Equation 1 and 2 respectively.

$$(\text{NI}) = \sum_{i,j=1}^{n} w_{ij} x_i \qquad (1)$$

$$\text{Out}_k = f(\sum_{j=1}^{n} W_{jk} H_j) = f(\sum_{j=1}^{n} W_{jk}\, f(\sum_{i=1}^{n} W_{ij} X_i)) \qquad (2)$$

In backward pass, the output is passed back to previous hidden layer by adjusting weights on the basis of error. The weight adjustment is determined by Equation 3.

$$\Delta w_{jk} = -\xi \frac{dE}{d\, w_{jk}} \qquad (3)$$

Where $\xi$ the constant adjustment value and E is the amount of error.

In our study, Backpropogation learning technique is used for learning of accurate or near optimal positional values and acceptable values geometric image distortion. A training sample is presented to the neural network. The desired output of the sample is calculated by calculating the value of $OUT_k$ . The desired output is compared by the actual output and the value of error is computed. Scaling factor is measured to determine whether an adjustment is required or not. The local error (scaling factor) is evaluated on the previous layer by specially considering the neurons with higher weights. The procedure is repeated until the amount of error become negligible.

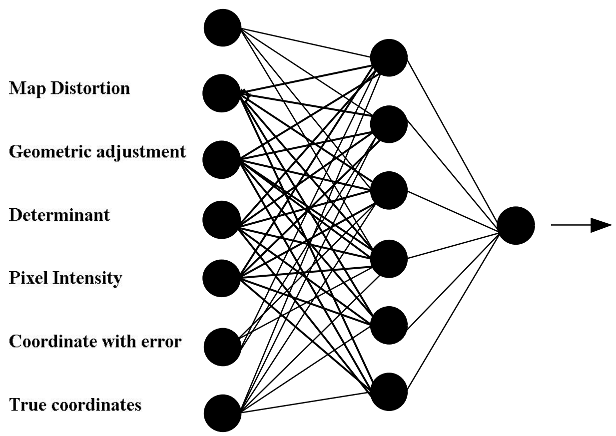


Figure 2 – Backpropogation neural network for ensuring accurate data acquisition

*<u>Standardization of Symbology/ Spatial Data</u>*

GIS Engineers spent good amount of time for selecting symbology and representing different attributes on GIS maps. A part of spatial data can suit user requirements if it is represented in the most common format which is already in practice. Every GIS owning company use symbology set to represent its assets. Symbols can represent the category of the data being mapped by adopting certain characteristics. These characteristics include symbol size, shape, orientation, texture, hue, brightness and lightness or simply they can be said as visual variables (Supermap Vector Map Symbol Library Exchange Format 2.0, 1999). The GIS which is built for proper management of information during hydrocarbon exploration also need to represent symbols which are specific to hydrocarbon industry.

In GIS interface for non-specialist user, it would be better to incorporate the same symbology. The user is well aware of that symbology and can easily browse through the maps. The standards of symbology and attribute data representation have not yet been developed in developing countries. SU Kehua et.al (2008) proposed virtual machine for cross-platform symbolization. Virtual machine technology is adopted to share symbols between various GIS applications. In the first step we proposed standardization in symbology while in the second virtual machine technology is proposed which have not been adopted yet.

The interface of GIS is equipped with a library which contains standard symbols for various domains of hydrocarbon exploration industry including (1). Geology (2). Geochemical (3). Pipeline (4). Environment (5). Natural Objects (6). Soil (7). Microbial prospects

These symbols are selected and finalized after coordinating with various companies through online questionnaire and later through a coordination meeting. Standardization is explained in Figure 3.

## 2. Material and Methods

A system namely GINU (Geographical Interface for Novice Users) has been implemented after the completion of study. The purpose of development was to provide flexibility in interface of ArcGIS to incorporate above mentioned innovations. The interface addressed the issues of (1). Friendly GUIs (2). Data accuracy and symbology in an integrated manner. The goal of GINU is to increase diffusion of GIS by improving the interface of GIS application. The use of GIS is limited in developing countries because of the above mentioned reasons. Especially, the managers of hydrocarbon exploration industry were reluctant to use GIS inspite of the fact that GIS is beneficial for going through various steps of hydrocarbon exploration. GINU integrated the concepts of multiple domains including Human-Computer Interaction, artificial neural networks and social sciences.

GINU is composed of two types of databases. One is to store spatial and non-spatial database just like normal database management in GIS software. An instance of spatial database is proposed (not actually embedded yet) to incorporate virtual machine technology which was proposed by SU Kehua et.al (2008). The second type of database is the one which handles attribute data. The interface is divided into information retrieval window, information querying window and information analysis window. Raw input by user is directed towards the appropriate module and will be retrieved by either spatial or non-spatial database as per requirements of the user. For Information analysis, the user is given with the option to perform three types of analysis.

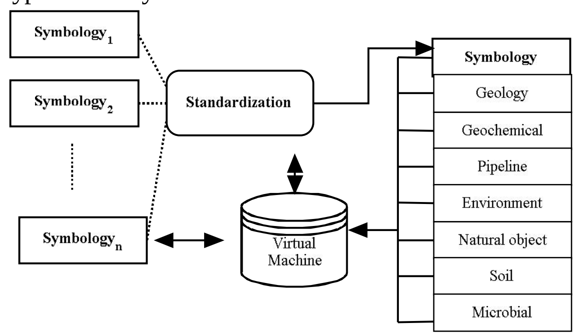


Figure 3 – Standardization of symbology through incorporation of virtual machine

***Statistical analysis***: The user will perform normal statistical analysis which is most common in industries. Normal statistical analysis can use methods of correlation, sum if, average if etc.

***Non-Statistical analysis***: Every analysis other than statistical analysis is placed in the category of non-statistical analysis. For example the user is interested to find terrains with large number of obstacles in reconnaissance survey etc.

***Validation analysis***: Validation analysis is performed to validate the accuracy of data incorporated in GIS. As stated earlier that positional accuracy or image geometric accuracy can be validated by using back-propogation neural network (BPNN).

The architecture of GINU is illustrated in the Figure 5. Validation analysis is quite innovative and incorporated in the system for testing purposes. So the results of backpropogation neural network for validation analysis are described in Table1.

Table 1. Results Summary of BPNN

| | **Training Set** | **Test Set** |
|---|---|---|
| Iterations trained | 2478 | N/A |
| No of Rows | 486 | 115 |
| Tolerance | 0.2 | 0.3 |
| No of good forecasts | 288 | 96 |
| No. of bad forecasts | 96 | 19 |
| Average MSE | 0.1724 | 13.254 |

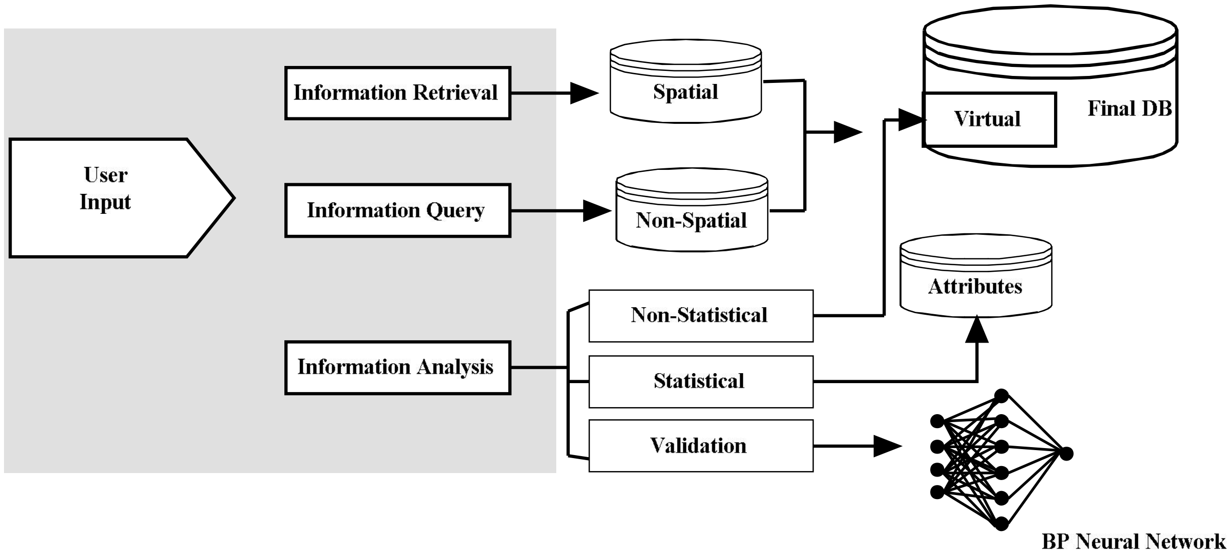


Figure 4 – GINU's Architecture

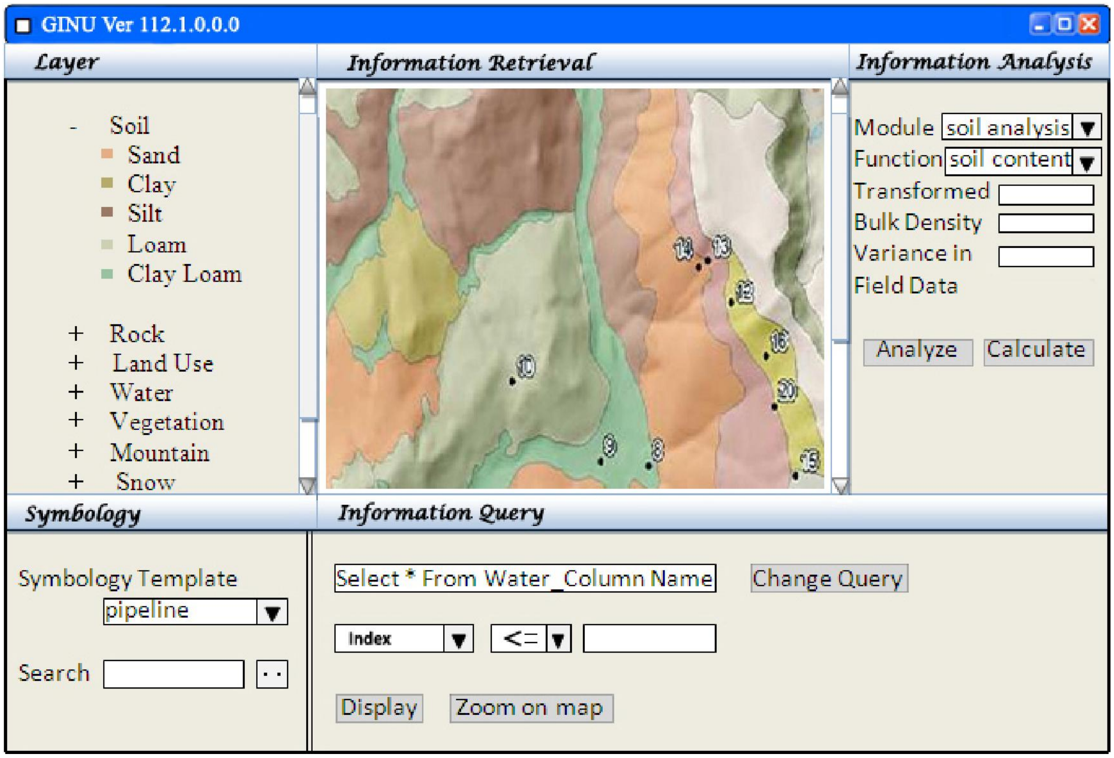


Figure 5 – Proposed GINU's Interface Design

## 3. Conclusion and Future Work

We have presented an overview of the reasons for non-diffusion of GIS in hydrocarbon and other industries of developing countries. We identified three reasons for non-diffusion. (1). Non-friendly GUIs (2). Unreliable accuracy of spatial data (3). Non-standardization of GIS symbology. For the first one we proposed few enhancements in existing GIS interfaces so that the interfaces become usable and easy for novice users. To deal with positional and imagery inaccuracy, backpropogation neural network is introduced which is trained on different ranges and new data is validated on the basis of those ranges. New data can also define certain change in previous range. For standardization of GIS symbology, all the organizations are motivated to follow standard symbologies. Virtual machine is incorporated to ensure standardization of symbology. A system GINU is developed to support novice users in GIS usage hence increasing the diffusion of GIS in hydrocarbon industry.

The work can be extended to actually include virtual symbology storage in the system. The validation of data for ensuring accuracy can also be enhanced by identifying patterns, trends and distribution of data in the existing database and to enforce new input to follow the same pattern and trend.

**Corresponding Author:**
Muhammad Shaheen, Ph.D (Computer Science)
Department of Computer Science
University of Engineering & Technology Lahore
Punjab, Pakistan. Tel: (92)331-4525045
E-mail: shaheen@uet.edu.pk,
shaheentanoli@gmail.com

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