Multi-Pipeline Geographical Information System Based on High Accuracy Inertial Surveys

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Abstract

A geographic information system (GIS) is a computer-based tool for mapping and analyzing existing features and events that happen on earth. The use of a GIS in pipeline integrity is an invaluable component as it allows users to view and geographically reference all data input into the system. With the data in place, custom queries can be performed that allow the user to visualize scenarios and make effective decisions.

This paper highlights a multi-pipeline GIS system and the high accuracy Geopig® inertial and caliper surveys required to obtain the data for it. The data collected from the survey included pipeline UTM coordinates, which are the basis of the GIS, information on pipeline features and anomalies, and metal loss data from past in-line inspections. The system is based on the ArcView® GIS Software with the ArcView 3D Analyst™ extension that allows both the cartography and pipeline data to be viewed in 3-D space. As a result, pipe defects and anomalies can be located efficiently and accurately. This helps to eliminate unnecessary excavations, as well as to coordinate, plan and schedule pipeline repairs and resources. The additional benefit of a GIS is the ability to store, manage and update a variety of information, for all pipelines from one database.

Geopig Technology

The Geopig is an internal inspection tool that provides pipeline mapping (UTM coordinates) and bending strain by means of the inertial navigation system, as well as detects and measures pipe wall deformations using the ultrasonic or mechanical calipers.

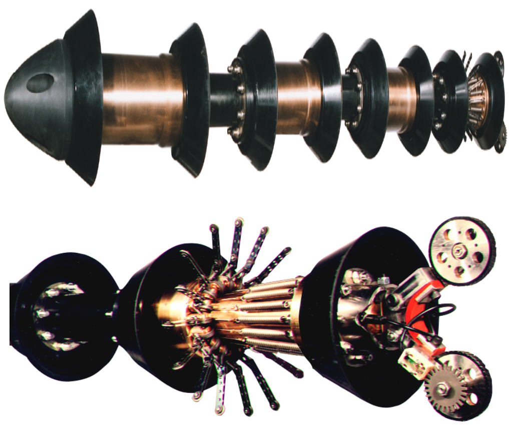

Fig 1. - 8"Geopig

The Geopig's main sensors are: inertial navigation system, mechanical/ultrasonic calipers, odometer wheels, weld detectors, pressure and temperature sensors. They are completed by data storage devices, interface electronics, micro-processor controllers, batteries, power management module, and electromagnetic pig tracking transmitter. The Geopig provides the following information:

- Pipeline plan and profile based on Universal Transverse Mercator (UTM) coordinates. This is obtained by combining the inertial survey data with the GPS coordinates of selected pipeline features spaced at 2 -5 km intervals.
- Curvature radius and bending strain in both vertical and horizontal planes

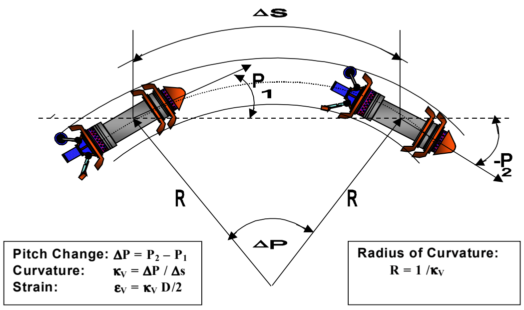

Fig 2. - Curvature and Bending Strain Computation

- Pipe internal diameter as well as location, size and shape of bore restrictions including dents, ovalities, wrinkles and permanent fixtures in the pipeline
- Girth weld location

Multiple runs can detect pipeline movement and pipe anomaly growth.

All this information can be used for creating the pipeline GIS.

Geopig Survey of PEMEX Lines

The main objective of the Geopig survey for PEMEX was to obtain UTM coordinates of 11 pipelines NPS 8 – 14 located in the Valley of Mexico, as well as to detect pipe wall anomalies, measure bending strain and correlate the data with the previous metal loss surveys in order to create a single GIS system that can be used in planning and conducting the pipeline rehabilitation program.

BJ contracted Sistemas de Información Geográfica S.A., SIGSA of Mexico to provide the GPS survey of the control points along the pipeline, as well as the digital cartography of the areas crossed by the surveyed pipelines in and outside Mexico City.

All the Geopig survey data can be viewed both in ArcInfo GIS software and in the BJ display software: Geodent and Geodisplay. Samples of plots created by those programs are included below.

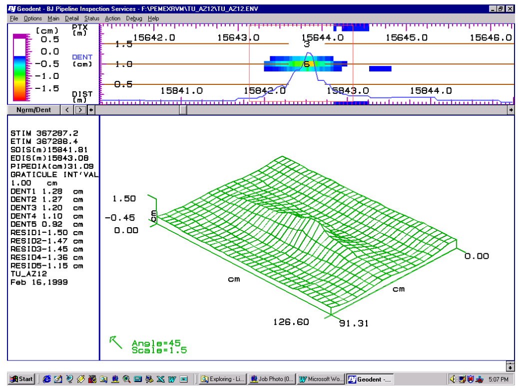

Fig 3. - 3-D view of a dent shown in Geodent

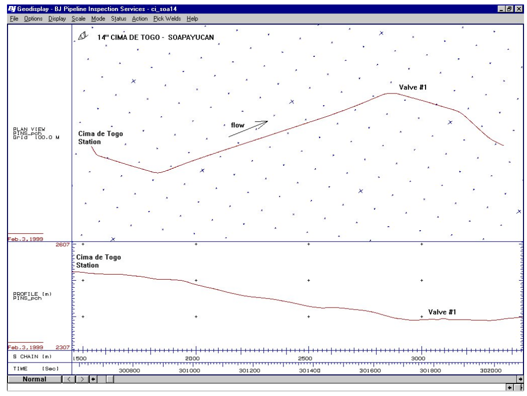

Fig 4. - Pipeline plan and profile shown in Geodisplay

The following digital information was generated for all the lines in order to create the pipeline Geographic Information System (GIS)

- Pipeline Northing, Easting and Height every 0.5 m
- Weld UTM coordinates, wall thickness and joint length
- Size, clock position and UTM coordinates of dents greater than 2 % O.D.
- Metal loss detected by Pipetronix and correlated with the BJ survey data
- Location of pipeline markers and GPS points

What is GIS

A geographic information system (GIS) is a computer-based tool for mapping and analyzing features that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it a valuable tool for explaining events, predicting outcomes, and planning strategies.

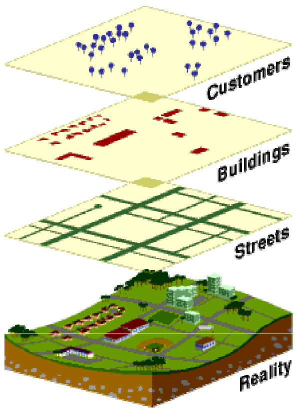

Fig 5. - GIS Schematic

Data used in a GIS is usually geographically referenced which gives the user a real world look at how features relate to one another. For data to be geographically referenced, a coordinate must be associated with it. The coordinate could be a latitude and a longitude, or some type of *x,y* grid coordinate pair. The advantage of geographically referenced data is that it can be combined with any data sources referenced to the same coordinate system.

A GIS typically works with two different types of geographically referenced models. These are known as the vector model and the raster model. In a vector model, all features are described as a point, line or polygon. For example, pipelines might be thought of as lines, and valves might be thought of as points. The vector model is excellent for describing discrete features (such as buildings) but not as good for describing continuous features (such as a lake or a marsh). A raster model is a grid where each grid cell (or pixel) has a value. This model is more like a scanned image where each pixel in the image has a color value.

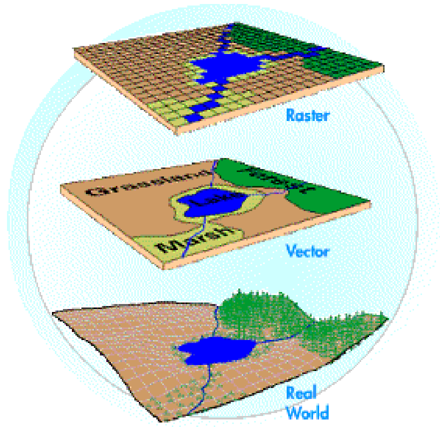

Fig 6. - Raster and vector data representation

Most information systems have some kind of database management system (DBMS) to help store, organize and manage data. The most common type of DBMS is a relational design where data is stored in tabular format. These tables contain common columns, which allow them to be linked together. Another type of DBMS that is gaining popularity is a spatial design. These data sets do not contain a common column, but rather a common reference point or area. In this way, all data contained in the same region will be spatially joined.

With a functioning GIS, queries and analysis can be performed on the data. These can range from simple questions such as:

- How many dents are contained in the pipeline?
- Who owns the land that this section of pipeline is built on?

to more complex analytical questions like:

- Which sites are best suited for a new pipeline?
- If I build a pipeline in a certain location, how will the community be affected?

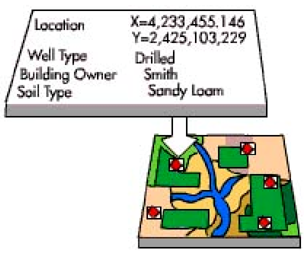

Fig 7. - Example of what data can be stored in a GIS

Proximity analysis can be performed if data is geographically. This aids in answering some of the following questions:

- How many houses are within 100m of the pipeline?
- Where is the nearest valve to this defect?

GIS for Pemex Pipelines in the Valley of Mexico

The generated pipeline GIS allows to display pipeline position (plan and profile) together with pipeline features such as girth welds, dents, metal loss, and strain in relation to known landmarks such as roads, buildings, political boundaries and hydrology. The system is using ArcView with the 3-D analyst extension to display both pipeline and vector map tile data.

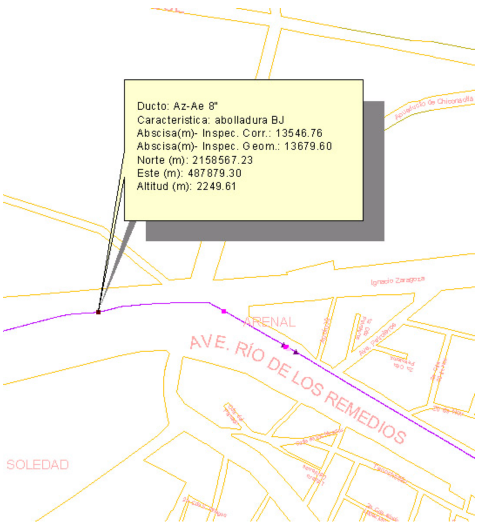

Fig 8. - Vector representation of the pipeline and surrounding roads

BJ Pipeline Inspection Services performed inertial and caliper surveys of eleven pipelines in the Valley of Mexico. The collected geometric data forms the foundation of the pipeline GIS. Additional data was supplied to BJ from past metal loss surveys, which also needed to be correlated and integrated with the pipeline geometric data. All data was geographically referenced, and combined to form a single GIS.

A vector model was used to create the data, which described the pipelines in terms of lines and all features in terms of points.

The pipeline themes were given attribute information describing the following:

1. Company that did the corrosion survey
2. Year when the corrosion survey was done
3. Company that did the geometric survey
4. Year when the geometric survey was done
5. Name of the pipeline
6. Diameter of the pipeline
7. Pipeline number

The pipeline number was the common field found in all data sets and was used to join the pipeline information to every feature on the line. The features of each line were divided into a ‘welds’ theme, a ‘client inventory’ theme and a ‘markers’ theme. Each feature was tagged with the BJ geometric survey information and supplied client information. This design will allow any user to access all information available for a given pipeline feature.

Along with the pipeline data, vector base map data was added to the system. This data contains a vector representation of all roads and city blocks as well as the street names, hydrology and political boundaries. This data was divided into many tiles, each one covering an area of 2.7km by 1.8km. The division was done to minimize the time required to draw a given area. A digital elevation model (DEM) for each tile was also created. The DEM was converted into a three dimensional surface where the pipeline and its features could be viewed in three dimensions.

Generalization was kept in mind when designing the GIS so that future data can be easily added to the system. ‘Date of survey’ columns allow multiple surveys to be entered so the user can query selected years or perform a comparison over many years.

Ease of use and accessibility to all information was kept in mind when designing this system. A map index extension was built for ArcView to handle all the map tiles and give the user point and click access to all of them. A ‘grid view’ was created to show all pipelines and the areas covered by the map tiles from which the user can click on an area and select a view to place the map tile into.

A separate view was created for each pipeline, except for areas where two lines paralleled each other. In these cases, both lines were placed in the same view. These views contain all the detailed information pertaining to the pipeline. Defect information such as dents, metal loss, lamination defects, inclusions and strains are shown as well as feature information. The features displayed are welds, valves, tees, installations and 2km marker posts. Since all data for a given pipeline is linked together, queries can be performed on any aspect of the line. These could be spatial queries, designed to find features in a given area, or tabular queries, designed to find features of a certain size.

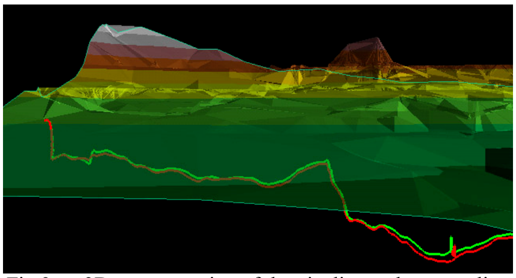

Fig 9. - 3D representation of the pipeline and surrounding terrain

The '3D Analyst' extension gives the ability to view the pipeline, its features and the surrounding surface in three dimensions. This can be very useful as it incorporates depth and height into the system. Pipelines can be visualized as they are in the ground and depth of cover can be seen. Not only can a pipeline height be queried, but surface heights as well.

Benefits of Pipeline GIS

The UTM coordinates of pipeline features and their relation to the landmarks combined with the GPS survey is a very efficient and accurate way of locating those features in the field. This is particularly important in the areas of high population density such as the Valley of Mexico, where there are many pipelines running in the same right-of-way and the access is usually difficult. The created GIS system helps to eliminate unnecessary excavations as well as to coordinate, plan and schedule pipeline repairs.

The ability to contain all data for these pipelines on one system should help in reducing the amount of duplicated data. It also allows for easy comparison of the pipeline survey data collected from several inspection tools performed in different years. Having all users working on the same set of data ensures the correct data is being used at any given time. Updates to existing themes or new data can be easily and seamlessly added to the system and visually inspected to ensure it fits with surrounding features. There is no need to create customized versions of the GIS to suite a specific person or group. Each user has the ability to view minimal details or complex details for every given feature. Every theme in the GIS can be turned on or turned off, thus tailoring the view to the user.

With all data being geographically referenced, relationships between the data are more apparent and the data itself becomes more valuable. The GIS gives the ability to create detailed maps, query data for effective solutions, visualize scenarios, and make complex problems easier.