Remote sensing and GIS technologies for route selection of "West-East Nature Gas pipeline"

Xiaoge Zhu, Yaoyan Zhang, Yiming Zhang, Hu Yan, Wang Shihong
Remote Sensing Department, Research Institute of Petroleum Exploration and Development (RIPED)
PetroChina Company Limited (CNPC). P. O. Box 910, Beijing 100083, China.
zhuxg@petrochina.com.cn

Abstract: The West-East Nature Gas Pipeline is a great project in China. Advanced remote sensing technology combined with GIS and GPS is used to select the favorable plan from various possible routes through interpreting the information of topographic landform, regional geology, disaster geology, traffic conditions and nature environment from remote sensing images. There are a lot of changes in geographical and environmental factors along such pipelines due to the rapid development in China. Image maps produced from new satellite data can identify these changes and be used successfully not only on route-selection studies but also on in situ investigation, together with GPS. Results from detail analysis provide necessary information and parameters for plan, design and construction of the pipeline and they are also the basic data for the pipeline database. The set of techniques has been applied on planning and designing several pipelines successfully.
Keywords: 3S technologies, route-selection of pipelines, image maps.

1. Introduction

A number of long-distance oil-gas pipelines are under construction or plan in China. Each of the pipelines is a complex system and relates closely to geological, geographical, economical, environmental and many other natural and anthropogeography conditions. The West-East Nature Gas Pipeline, one of the four largest projects at the beginning of the new century in China, is one of them. As nature gas releases less pollution than coal (the most common fuel in China), the West-East Nature Gas Pipeline will send the clean and convenience energy to be utilized along the whole pipeline, to improve greatly the environmental conditions and welfare of millions of people. It will also play a significant role in national economic development, especially to boost the progress of the low-developed western region.

The West-East Nature Gas Pipeline passes through seven Provinces (Autonomous) and Municipalities. There are many different geological regions along its route and a lot of changes in geographical and environmental factors due to the rapid development in China especially in the eastern region.

Remote sensing techniques combined with GIS and GPS offer the way in an unbiased and cost-effective manner on planning and designing the routes of long-distance oil-gas pipelines, for example [1-3]. The advanced 3S technology has been used in route selection of the West-East Nature Gas Pipeline.

2. Comprehensive Interpretation for Route Selection

In the West-East Nature Gas Pipeline project, fifty-two TM and ETM images were used to make a mosaic image, geometric corrected by 1:250,000 maps, ranging from the beginning to the ending of the Pipeline. The mosaic image gives the direct and visual description of the whole region along the pipeline as a colourful and macro-scope display. Several different designed routes for this pipeline are overlaid on the mosaic image to carry out the comprehensive studies and comparison of various topographic landform, regional geology, disaster geology, traffic conditions, nature environment and so on, with reference to the geological, hydrographic, seismic and other environmental materials.

The Analytic Hierarchy Process (AHP) method [4] incorporation with expert knowledge is applied for quantitative analysis, by means of GIS platform for spatial analysis and statistic. The pipe route comprehensive evaluation system is established, which includes twelve data layers characterizing four factors such as pipe length, traffic condition, crossed barrier and terrain. Every factor and sub-factor were given a certain weighing offered by expert experience and knowledge and determined by the judge matrix of AHP. Many important parameters used here come from the interpretation and analysis of remote sensing images. The parameters include total length of a route, the lengths through different terrains, especially the length across the earthquake zone with intensity >Ⅷ, number of times crossing big rivers and highways, as well as traffic condition. The result gives a grade for every evaluated route, which promotes the study of remote sensing route-selection from qualitative to qualitative and quantitative stage.

The most favorable scheme is selected and proposed after the study.

A dynamic 3D display, using digital elevation model (DEM) and the mosaic image, is applied also. It demonstrates actively the landforms and physiognomy features of the area along these routes, and gives deep impression to decision-makers. Furthermore, the route length counted from the 3D image is much more accurate than that counted from the 2D image.

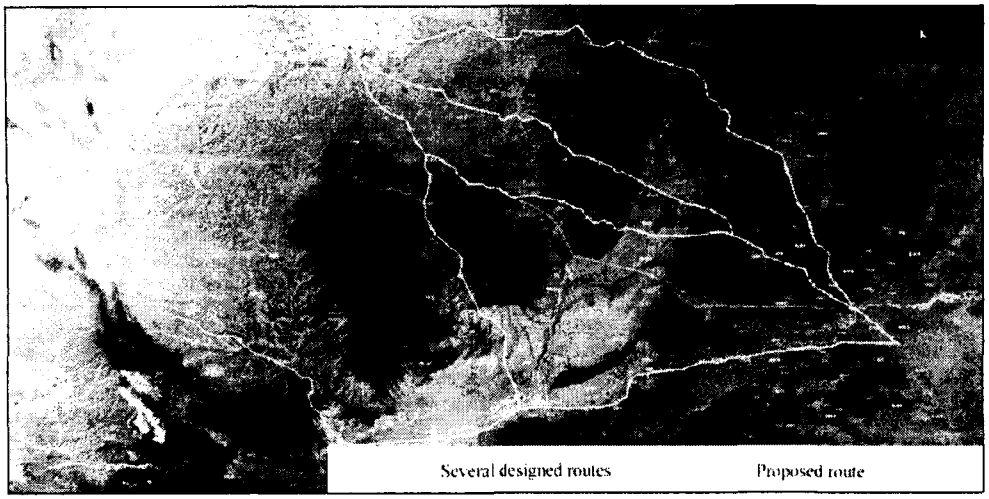

Fig. 1. TM mosaic image for route comparison and selection

Figure 1 shows the mosaic image for route comparison and selection, and the proposed route is shorter and has the better condition of landform than others.

3. Detail Analysis on Key Section

1) Image Map and Database

Whereas many very important factors for planning and designing pipelines could not be found from existing maps, especially in eastern China as the fast development in recent years, but remote sensing images can give most new information timely and precisely. For certain eastern section of the planned pipeline, the image products of different scales were produced from SPOT 10 m resolution data received recently and corrected by 1:50,000 — 1:100,000 maps. These image products contain all the information of remote sensing images, but have the spatial accuracy of corresponding maps [5]. They can be named as image maps for easy understood by users. The image maps delineate and characterize natural and people-made features such as rivers and mountains, vegetation and roads, villages and cities to offer the most recent information.

The features relevant to the pipeline (linear rivers, polygon waters, dykes, roads, highways, railways, villages and cities, etc) were extracted from the image maps covering an area of 5 km—10 km along each side of the planed pipeline, in order to revise the old maps. Data fusion methods of HIS transformation and PCA-Principal Component Analysis [6] are used to fuse the 10m resolution images of SPOT or ETM panchromatic band with 30m resolution color images of TM or ETM data for feature extraction. Artificial neural network [7] is used to classify images (by PCI software) for automatic feature extraction by computer, especially for the vegetation condition.

The average accuracy is 20.6m from 453 examined points selected randomly among nineteen 1:50,000 maps. These features, vector data, are stored as separated lays, in database based on GIS technology. They can not only identify certain features and be displayed as lines and polygons on a hard copy map as a revised map, but also contain a wealth of added meaning and related information valuable to the users.

These spatially accurate image maps, revised maps and GPS have been used on in situ investigation and often lead to helpful results. The feature data stored in common format of GIS database can be manipulated by clients on their GIS platforms, and set up a foundation for future digital management and operation of the nature gas pipeline.

Figure 2 is an image map overlaid with extracted vector lays and used for route optimizing. The proposed scheme for this part is 480m shorter than designed route.

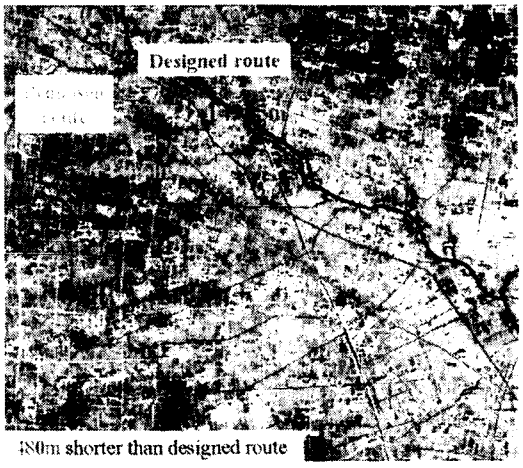

Fig. 2. Image map used for optimizing route.

2) Analysis of Changes for Key Engineering Point

Eleven time-series images of Landsat MSS, TM and SPOT HRV received from 1975 to 2000 are used to analyze and evaluate the evolution of the Yangtze River at the planned crossing part. The flooded areas in different seasons and years on remote sensing images are analyzed carefully in order to understand the stability of the riverbed and banks in this section. The variation trend of the riverbed, the change direction of the banks and the possible effect to the pipeline are forecasted

The economic development is very fast in recent years in the region along the Yangtze River where the planned pipeline will cross through. There are new or expanded residential and industrial areas, highways, roads and irrigation systems. The multi-temporal remote sensing images give the clear information about such variation and image maps produced from these remote sensing data offer necessary information for route plan and on site exploration.

The suitable crossing location is suggested based on these studies and other relative materials. The result gives the valuable information for the final route design.

4. Conclusions: 3S and Digital Pipeline

Digital pipeline is the main feature of pipelines in 21st century. It will have all the relevant data, graphs, images and other information digitized, assembled and stored in corresponding databases in computers. These different kinds of information can be used and analyzed comprehensively, displayed and demonstrated visually, inquired and updated conveniently. It is the new development on plan, construction, operation and management of pipelines.

The West-East Nature Gas Pipeline will be built up as a Digital Pipeline. Remote sensing technology together with GIS and GPS can be used as the necessary tool to acquire the most new information timely and to set up, update, and management database for planning, construction, operation and monitoring of the digital West-East Nature Gas Pipeline.

The whole set of techniques has been applied on planning several other long-distance pipelines successfully.

Acknowledgement

This study is the result of the hard work by all members of GIS group in Remote Sensing Department, Research Institute of Petroleum Exploration and Development (RIPED), PetroChina Company Limited (CNPC); and supported by Wang Bin-huai (Project manager), Cheng Xiwu (Chief engineer), Cheng Zhongyuan (Chief engineer) and leaders of China Oil-gas Pipeline Bureau of China National Petroleum Corporation (CNPC), as well as managers of the West-East Nature Gas Pipeline project and PetroChina Company Limited. Authors thank sincerely all of them for their support and cooperation.

References

[1] IN-RIMT, 2002, Delineation of corridors for pipeline routings through remote sensing and GIS techniques at Vadinar, Gujarat, India. Available at: http://www.inrimt.com/borgujrat.htm

[2] K. B. Fung, D.W. Fraser, R.P. Gauthier, 2002; Application of Remote Sensing Data for Monitoring of Gas Pipeline right-of-Way. Available at: http://www.ccrs.nrcan.gc.ca/ccrs/rd/sci_pub/bibpdf/3339.pdf.

[3] William L. Pickles, Donald G. Price, 2002; Geobotanical remote sensing Techniques For Natural Gas Transmission Infrastructure Systems using advanced Hyperspectral, multispectral, and Radar Imaging. Available at: http://www.netl.doe.gov/publications/proceedings/02/naturalgas/1-1.pdf.

[4] Jiang Qiyuan, 1993, Analytic Hierarchy Process, Mathematics Model. Beijing, China: *High education publishing*

[5] EarthData 2002, Map Products, Data Applications. Available at: http://www.earthdata.com/index2.htm.

[6] C. Pohl, J. L. Van Genderen, 1998, Multisensor image fusion in remote sensing: concepts, methods and applications. *International Journal of Remote Sensing*, Vol.19, No.5, 823-854.

[7] Zhang Baoguang, 1998, The application of artificial neural network to classification processing of remote sensing digital images. *REMOTE SENSING FOR LAND & RESOURCES*, No. 1. 21-27.