Geoprocessing application in geophysical surveys management – Land environment

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Abstract

This paper demonstrates the importance of using geoprocessing techniques for the perfect planning and development of land geophysical operations in Brazil.

Introduction

According to BNDES[1] (2009) the revenue of the service and extraction equipment of oil and gas production sector was around U$ 270 billion in 2008. In this scenario, the necessity of rendering service companies which provide acquisition of geophysical data services to prepare themselves in order to conquer a share of that market becomes evident. Thus, the steps - acquisition design up to the performance of the survey itself, depend on detailed researches in support of environmental conservation, and strategic planning for the acquisition. Therefore, an early study of the decisions to be mad, such as: project execution term, prior knowledge of the territory and its spatial boundaries are required, always seeking the best cost/benefit in project deployment.

Thus, this paper demonstrates how the detailed study of the region can be strategically feasible and productive, by applying such techniques and innovative technologies. Therefore, the objective is to foster the use of this area of knowledge in geophysical surveys. Therefore, the following variables were analyzed: elevation, vegetation, geology, Digital Elevation Model (DEM), land use, hydrography, environmental conservation units and satellite images. Through analytical criteria and use of geoprocessing techniques, it is possible to assist managers in making decisions from start to end of the survey.

Applicable technologies in geophysical surveys - Seismic and other methods

With the technological advances of orbital sensors at each new release, generally, we have an improvement in spatial, temporal and spectral resolutions. It leads to more accurate answers, thus enabling the use of remote sensing techniques. From the study of Laake and Insley (2004) relevant pieces of information were extracted from sensors for use in planning the survey. Another beneficial use of this technique is the geological mapping shown by the Carrino and Souza Filho (2007), where they compared date from Synthetic Aperture Radar sensors (SAR) of three different satellites and aerogammaspectrometry data, seeking rock discrimination and identification in Brazilian Amazon forest region.

For topographic survey in more anthropogenic areas, systems with Real Time Kinematic technology (RTK) can be used. However, this is not advisable in dense forest environments, due to the interference of vegetation in the signal. Though, there are acquisition techniques by laser; the so called Light Detection And Ranging (LIDAR) detailed in Silva and Hudak (2013). The same bring benefits even in dense forest environments compared to the traditional method with total stations or RTK. This allows the generation of the same products as the traditional survey, despite the poorer accuracy still accepted in acquisition patterns of such data (BEAUBOUEF; WAGAMAN; SFARA, 2005).

Another widely used technology is the Unmanned Aerial Vehicles (UAV) known as drones and Unmanned Aircraft (UA). In Brazil they were called "*Veículos Aéreos Não Tripulados"* (VANT). Various types of sensors can be loaded in such equipment such as LIDAR; infrared, video and DSLR cameras; ultrasonic; magnetometer; gravimeter; gas; differential thermal imager.

From the use of VANT with its numerous sensors, a lot of services may be used in seismic and non-seismic surveys. Such surveys may comprehend the simple acquisition of high resolution images, or even acquisition of magnetic data.

According to Barnard (2008) some of the positive points for the use of VANT are:

- Magnetic and gravimetric data with less noise due to the reduction in the size of the aircraft;
- Magnetic acquisition in times where the incidence of background is lower, as a result, the signal noise ratio is better compared to the traditional method;
- Shorter revisits period (independent from the sensor used);
- Acquisition independent from weather conditions (independent of the sensor used);

Although they are tools with great potential, studies such as those of Silva (2013) show that they depend on specific permits ANAC[2] DECEA[3] e ANATEL[4] to have a regularized operation in Brazil.

Another useful tool in all survey steps and which is described in the following section is called Spatial Data Infrastructure (SDI). In addition to a Volunteered Geographic Information software (VGI), adapted to the seismic working conditions.

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Previous data catalog

The first step before the survey planning is to obtain vector data and satellite images of the relevant area. Although the easy access and visibility whose tools, such as Google Maps/Earth have brought to Geoprocessing sector, one cannot think that the single use of the same is sufficient to plan and operationalize an acquisition. Surely they help in this task, but they are not the only ones.

Based on the definition of geospatial data, that is the representation of a phenomenon or occurrence which has location and extent. It should be realized, therefore, that all land seismic survey or not, may be comprised into this premise, once everything which is acquired has its spatial component. Therefore, so that the cataloging process be done properly, it becomes necessary to use a SDI, as described by Castro (2013), thus, enabling this way, the access to spatial information in a systematized and centralized manner (Figure 1)

SDI is responsible for organized access of geographic information of all the study. At the application layer, the user or software, has access to geographic services, such as, for example, interpolation processes. But also, to another application, the VGI, which is the democratizing agent of geographic information for that survey team because it acts in a collaborative manner. Thus, any member can contribute by inserting a spatial data and interact with the tool.

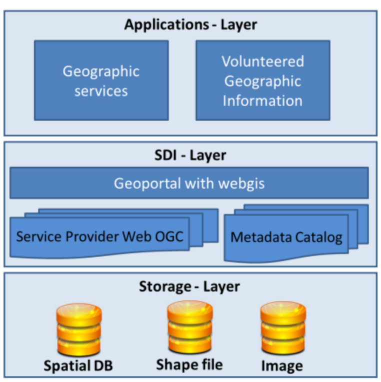

Figure 1 – Spatial Infrastructure scheme

However, nothing forbids users from accessing the SDI directly, without using the application layer, and using it as a communication process by a simple request, made with tools adapted to the network. In order to do this, it counts on a geo-portal that accesses the web service provider, standardized by the Open Geospatial Consortium - OGC, as well as a metadata catalog. This infrastructure is coupled to a storage layer, consisting of a spatial database system, file directories shapefiles and images, which are used as background in the presentation of information.

Therefore, SDI allows the correlation between information on a more active form as well as increases the efficiency in searching the information. Important factors, due to the need to plan before the actual execution, should be considered.

Planning

The operating planning step always serves as the basis of all process and it is on this step that several geographical factors should be considered. Since these ones can directly influence the logistics work of acquisition and will comprise all the subject matter of the planning, they are very important. Based on the flow shown in Annex 1, the work to be done becomes more efficient, for example: Whenever a survey preparation step starts, it is necessary to acquire the data to be used in agencies such as IBGE[5], INDE[6], ANA[7], IBAMA[8], INCRA[9], DNPM[10], CPRM[11], EMBRAPA[12], MMA[13], GOOGLE, State Environmental Agencies and Satellite Images. Thus, when all these data are entered in SDI (inputs step - Annex 1), with the deployed database, it is possible to perform geoprocessing (process step - Annex 1) and information analysis, which allows to generate different thematic maps, important for the project planning and execution, such as map of wetlands, DEM, slope index, environmental protected, vegetation, elevation, geology, hydrography and lithostratigraphy areas (products step - Annex 1). Finally, all this information will generate the delivery of various products that will guide the work of other fronts.

An input widely used in GIS analysis is the DEM. One way to create it is from images of the type Shuttle Radar Topography Mission (SRTM) provided by NASA[14]. In Brazil EMBRAPA offers these same images already processed and refined. After the appropriate cataloging of the images, the interferometry technique is applied, as described by Moura, Fonseca et al (2006) using the spectral response in the microwave band. This allows to obtain information on the structure of the three-dimensional targets in the image. The process makes the comparison between two radar taken images from slightly different points of images for elevation or information changes on the Earth's surface.

Therefore, using the ArcView software and its other applications (ArcMap, ArcCatalog and ArcToolbox) through the 3D Analyst extension> Contour made possible the extraction of image contours. Using it as soon after as an input in the DEM creation with the same 3D Analyst extension> Create TIN> Create TIN from features. After its creation, just sort the symbols.

We can present some maps prepared in the planning step of a seismic acquisition in this paper, such as the case of a 3D survey in the Solimões Basin. This basin is marked by its drainage density, being thus necessary to estimate the amount of forecast points located within the water mass polygon. We used for that, the concept of spatial search. Thus, these points could be considered as not materialized, commonly called skip. For the generation of the polygon to be used in spatial search a survey of

[5] Instituto Brasileiro de Geografia e Estatística;
[6] Infraestrutura Nacional de Dados Espaciais;
[7] Agência Nacional das Águas;
[8] Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis;
[9] Instituto Nacional de Colonização e Reforma Agrária;
[10] Departamento Nacional de Produção Mineral;
[11] Companhia de Pesquisa de Recursos Minerais;
[12] Empresa Brasileira de Pesquisa Agropecuária;
[13] Ministério do Meio Ambiente.

rainfall index in the region was performed, with its proper time frame, where the dimensions and history of flood rivers maximum were surveyed. We used a flood channel model created from the DEM, making it possible the delimitation of the water mass polygon.

When executing the spatial search from the generated data, it was possible to map the not materialized points. Arcview Software was used for this process, having the hydrographic data from ANA and raster from EMBRAPA as vector basis (Figure 2).

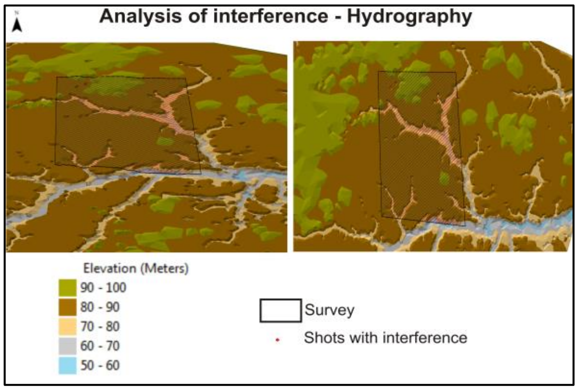

Figure 2 – Analysis of interference – Hidrography – Solimões Basin

The red dots represented on the map correspond to the likely skip that are below the quota of 70 meters in the river flood channel in rainy periods.

After creating the DEM, it is reused together with the hydrological information and the SRTM itself by creating a polygonal vector ArcView. These inputs allow the generation of flooding maps of intermediate, advanced or critical scenarios (in flooding periods), by vectoring of the “lower” zones image (Figure 3).

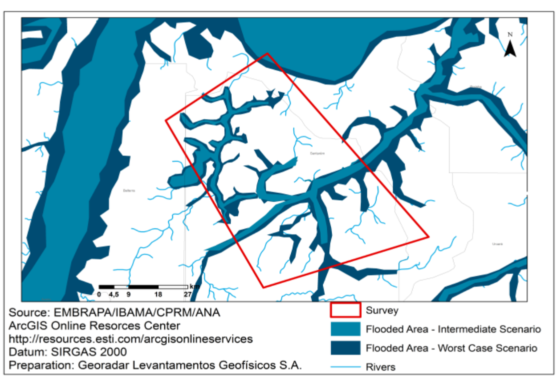

Figure 3 – Flood map – Amazon Basin

Another product is the "Yield Mapping", which is the analysis of several variables, such as slope and elevation, using for this purpose the maximum likelihood method - CreateSignatures in Multivariate (SpatialAnalyst Tools). This method creates an ASCII signature file containing classes defined by input sample data and a set of raster bands, with the extension * .gsg. Therefore, we define values for each type of productivity in relation to the slope of the acquisition land (Good, Medium and Low), creating a signature that will compose the calculation of variance-covariance of information. Each selected pixel receives a certain value and type, which will be captured in the image composing the productivity map (Figure 4).

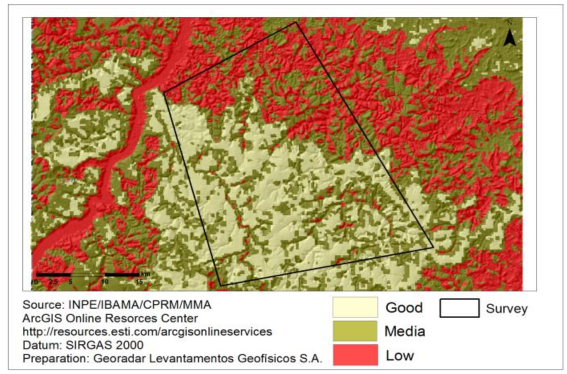

Figure 4 – Productivity Map - Parnaíba basin

Through satellite images treatment, it is also possible to extract key information for planning. For mapping land access, Google images can appear, depending on the area, resolutions that allow to view clearly secondary accesses and roads or highways. As it is a free datum, it eases vectoring (Figure 5). However, when a project is in an area of low resolution or areas with cloud cover, the purchase of the images may be required. Since mapping the accesses is essential in the planning step, but also in the actual deployment, it should be made, as it is the case for seismic acquisition using solely vibration sources in access for carrying out the survey. In this case, we suggest medium resolution images, for example, RapidEye with a spatial resolution of 5 meters. The same has a high rate of revisits for taking pictures, because its constellation has 5 satellites. Consequently, the amount of existing images in the collection makes this option a good alternative in assisting the accesses monitoring, generating more precise maps of the areas (Figure 6).

It is possible to see a maps differentiation from the images in the delimitation of accesses to be vectorized. As the Survey is located in coastal area, the images displayed by Google are under cloud cover area, which hinders this vectorization. In contrast, the collection of images RapidEye that imaged the same area in medium resolution allowed the identification of access and other interferences to the survey.

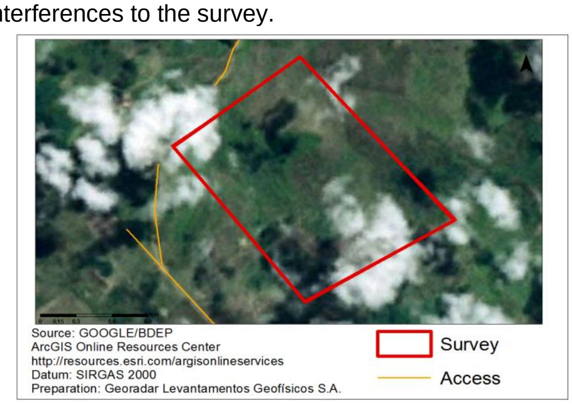

Figure 5 – Example of low images - Sergipe-Alagoas basin

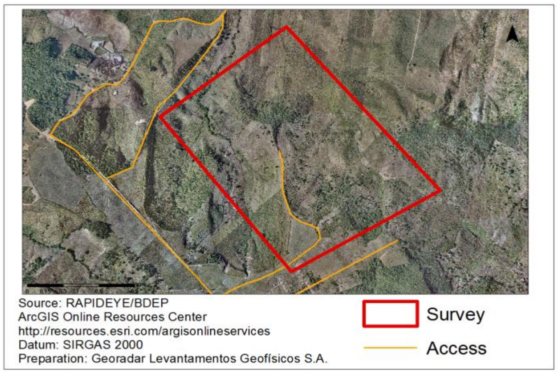

Figure 6 – Example of medium resolution - Sergipe-Alagoas basin

In addition to Google, there are other free images that allow us to analyze land cover such as the Land Remote Sensing Satellite images (Landsat), which aimed at multispectral mapping for high resolution Earth's surface. Currently, it is mostly used by EMBRAPA in mapping the spatiotemporal dynamics of land uses and its applications (EMBRAPA, 2015). These images sequence with the launch of Landsat 2,3,4,5, 7 and recently 8 started operating in 2013 with resolutions of 30 meters. By the method of maximum likelihood - CreateSignatures, as well as the Productivity map, such images are able to generate maps of Use and Land Occupancy also by classes defined according to the following map (Figure 7):

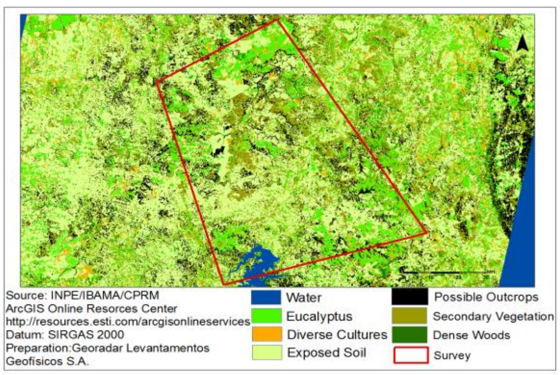

Figure 7 – Land use map – São Francisco basin

The application of such techniques is only made able in a System Information Geographic Ambient (SIG), where it is allowed to analyze wide range of variables in a supervised way simultaneously, which aggregate value to information (products in Annex 1) in form of map.

Operating Monitoring

During the course of the operation several work fronts operated synchronously. For that, it is necessary to preserve and use the correlation existing in the acquired data. With the proper feeding and the use of SDI, it is possible along the acquisition progress, to generate operating maps. By integrating relevant information at each step, such as: in the permitting front, step preceding the others, the forecast pre-plot is entered SDI as input. Since this is the basis for the acquisition, the georeferenced points allow the permit man be located in the field, using navigation devices such as Global Positioning System (GPS) for proper discovery of the landowners. After the cadasters are completed and the landowners coordinates collected, data are entered in the SDI. Consequently, the progress map of this front is allowed to be seen at any moment.

Soon after, considering that the coordinates were acquired with a traditional system, we have new information generated by the post-plot that is the materialization of the previously forecast points. As the foregoing forecast suffers interference along the acquisition, it is necessary that it is inserted into the structure as a new version of the forecast coordinate or a new datum. Again, it is possible to design a project progress map and analyze potential problems that may impact the development of subsequent fronts.

The non-seismic data acquisition is necessary in some surveys, which also contributes greatly in generating relevant information. Therefore, it is necessary that data acquired in field are entered into the SDI. So, we use the processing of anomalies studied to correlate them with the geological information obtained through remote sensing techniques, thus, refining the area geological model, therefore, adding value to information, which certainly helps the operation of other fronts, such as drilling. As a result, the estimate of the type of equipment to be used in each section is more assertive, generating less mobilization rework.

A full environmental assessment is necessarily required throughout the survey. In this step, called Area Recovery, VANT systems can be used, for the simple fact that they are able to acquire images in a short time, which allows a careful analysis of comparison between the start and the end acquisition works scenarios. Another advantage of such tools is the possibility of generation of vegetation type profile of the area from remote sensing techniques. In addition, the use of aerial images can prove the degree of ground cover or the existence of erosions and or grooves in the polygon of the activities.

As the SDI allows the inclusion of spatial information of each front, such photos of the performance of activities and information about the found vegetation, a consultation in the area of interest is sufficient to check for areas to be recovered or objects to be removed from the environment. This generates the necessary input for the recovery team to perform the service. All these changes are reinserted in the SDI as photos and reports for proper confirmation to environmental agencies.

The Quality Control step, which permeates all other fronts aims to assist the deployment of the activities of other fronts. Thus, all data generated in each of the steps undergo a previous validation before being entered in the company SDI. The main tool responsible for this validation and visualization is the webgis application (Figure 8).
The webgis spatially correlate the variables in question. This structure allows the management of information, bringing more concise and adequate results. Another point to note is that these visualization tools provide the history of that point represented virtually. At any time, all

team members can experience what has been acquired by integrating maps, photos, videos and texts in so-called story maps (ESRI, 2013).

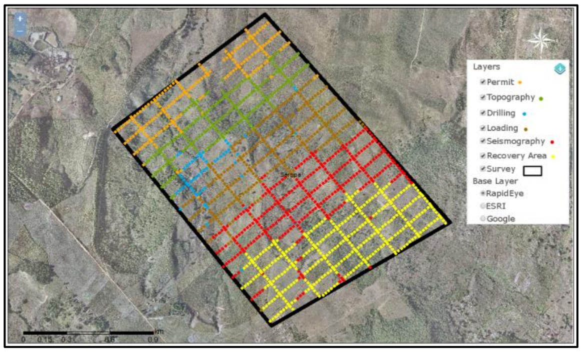

Figure 8 – Application webgis - Sergipe Alagoas basin

Benefits of using geoprocessing

At each step of land seismic acquisition process we observed positive points, such as:

- Decision-making in operating planning step;
- Forecasting not materialized points and the possibility to predict losses in project execution;
- Improved productivity forecast;
- Better prediction of possible areas of interference to the seismic source;
- Monitoring projects through progress map in actual time performance;
- Forecasts as to the difficulty or ease of drilling shots points (for explosive sources);
- Actual-time display of processed magnetic or gravimetric anomalies;
- Creation of story maps for each survey.

Conclusions

In this new technological scenario, where data should be available to all and in an integrated way, the role of technologies such as SDI and its applications as integrating agents of the geoprocessing techniques to be used to add value to the products of a geophysical survey is clear. This speeds the decision-making at every step, which certainly means project costs reduction with increased quality of the survey.

Technical portraying throughout the work, remote sensing, vectorization, algebra and geostatistics maps demonstrate the potential that this area of knowledge can bring. Of course, there are others that are also applicable and should be further studied.

Advanced technologies such as VANT are being used abroad and should be widely used in Brazil, since they offer many advantages over existing techniques.

Acknowledgments

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Annex 1

PROCESS FLOW – SEISMIC GEOPROCESSING