THE SIGNIFICANCE OF SPOT IMAGERY TO GIS APPLICATIONS: A COMPARISON OF DATABASES, THEIR ACCURACIES AND USES

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Abstract: SPOT imagery has been available for many years, but its success and usefulness has been limited by workstation data handling capabilities, cost, and the lack of proven application need on the part of local and regional users. With recent innovations in data handling capabilities and production software, SPOT imagery is becoming a more useful product for a more diverse set of users. This paper provides a comparison of current map derived vector databases with SPOT raster data, considering accuracies and potential applications.

The comparison will involve United States Geological Survey (USGS) 1:100,000 Digital Line Graph (DLG) data, vector DLG data bases that will be developed from 1:24,000 USGS maps, and SPOT imagery. The data sets are compared based on the usefulness to regional level users, whose areas of responsibility encompass 2,500 to 250,000 square miles. The data set accuracies discussed in the evaluation include metric, temporal, and feature completeness. The emphasis is on providing a useful understanding of the significance of SPOT imagery to regional GIS applications.

Key Words: Database, Accuracy, Metric, Temporal, Feature, Regional, Orthorectified, Image Mosaic

INTRODUCTION

Many local and regional users have begun or are about to begin developing a map graphic data base, the graphic portion of a Geographic Information System (GIS) database. They address this issue in three ways, create the map graphic data set themselves, have someone create the map graphic data set with user specific graphic data included, or by purchasing map graphic data off the shelf from a company that creates a generic data set to address many potential uses. To minimize costs the user wants to purchase a map graphic data set off the shelf, that allows for the integration of additional user specific information that is needed.

This paper will discuss and compare three "off the shelf" map graphic data sets for regional use. For the regional users there have been off the shelf digital databases available from both the USGS and private companies that provide vector data sets that can play a role in implementing a GIS. The two most common vector data sets are the 1:100,000 DLG and the U.S. Census TIGER line files. In addition the USGS is beginning to develop the 1:24,000 DLG vector data set. For this paper we have looked at the existing 1:100,000 DLG and the 1:24,000 DLG that will be developed, and compared them to SPOT imagery, which is in raster form. For the comparison we are using SPOT imagery that has been enhanced through triangulation, orthorectification, and mosaicking to increase the positional accuracies of the image data. The TIGER vector data will not be discussed in this paper because the metric accuracies are no better than the 1:100,000 DLG vector data.

In the past few years raster imagery has begun to emerge as a useable data set within the GIS technology, mainly due to the innovations in hardware and software. Users can routinely handle and process the large amounts of data associated with digital imagery. With new software capabilities it is possible to create mosaicked SPOT images, with proven metric accuracies of 50 feet. If you compare that to the metric accuracies of the existing 1:100,000 DLG and the developing 1:24,000 DLG you begin to see the potential for using SPOT imagery to support GIS applications.

Regional Emphasis

For discussion we will divide the users into three general categories; national, regional and local level users. The regional applications are the focus of the discussion. The regional group would include users with areas of concern between 2,500 and 250,000 square miles. This level of users includes State and Provincial agencies concerned with the spatial mapping and assessment of activities relating to the administrative region. It also includes groups within states with more specific interests such as a state forestry department, department of natural resources, a utility company, a large county, or special interest groups including county consortiums, water shed regions, and unique regional environmental areas, such as the Great Lakes region or western desert regions. The users at the national level would include those with areas of interest larger than 250,000 square miles, for example multiple state interest groups, large national interest groups including the U.S. Federal offices of Forestry or Agriculture. The local group would include those interested in smaller areas and much more geographic detail than what can be seen in any of these map graphic data sets. The groups associated with this level user would include counties, a city/county/utility consortium, or engineering groups.

DATA ACCURACY

There are three map graphic data accuracies of importance that are discussed here (see Table 1). Metric or positional accuracy , temporal or "change over time" accuracy and feature completeness accuracy. All three accuracies effect the ability of the user to visually interpret the graphic information allowing for a comprehensive area assessment in conjunction with the other data sets of the GIS.

TABLE 1
ACCURACY COMPARISONS

DATABASE	BEST CASE ACCURACIES		
	METRIC	TEMPORAL	FEATURE
SPOT	50′	1-2 Months	Image (1)
DLG 1:100,000	165′	2-20 Years (2)	Select Features (3)
DLG 1:24,000	40′	2-20 Years (4)	Select Features (3)

(1) 10 meter pixel image data/orthorectified and mosaicked
(2) Many are 10 years or more
(3) PLSS Grid, Boundaries, Transportation, Hydrography, Hypsography, (can purchase as individual data or all)
(4) Many hard copies are 10 years or more, but new photography will be used to generate the new 1:24,000 DLG dataset

Metric Accuracy

The metric or positional accuracy relates to the matching of the features in the map graphic data sets to the actual locations on the surface of the earth, as defined by a standard reference system. For a high degree of metric accuracy the map graphic data must accurately represent the information on the ground for the purposes of measurement of distance and direction. To be considered a scaled representation of the surface of the earth an image, whether satellite or aerial photo, needs to be corrected, or rectified, due to sensor induced and ground surface distortions. Because the DLG data, at either scale, is developed from photography, it too is influenced by this rectification process. It then goes through the additional process of being collected in vector form, as lines, points and polygons in the DLG data set.

The metric accuracy of uncorrected SPOT imagery can be as great as 1000 meters, which would not be used to support GIS applications. However if multiple SPOT images are run through a rigorous simultaneous block triangulation solution and then orthorectified using existing or newly generated Digital Terrain Model (DTM) information, the image distortions caused by the sensor and the undulations of the earths surface can be corrected for a final image mosaic that achieves an accuracy that easily supports GIS applications for regional use.

In addition, because the techniques used for the correction of the images involves using existing ground control, it is very easy to compute horizontal coordinates, (latitude, longitude) for any pixel in the digital image. The elevation can be computed from the DTM for the area. The metric accuracy then becomes a function of the pixel resolution, the control source used in the triangulation, and the accuracy of the DTM used in the orthorectification process.

Orthorectified SPOT image mosaics with absolute horizontal accuracies of 50 feet are available today. The absolute horizontal accuracy associated to the existing 1:24,000 USGS Quad sheets is 40 feet and the USGS 1:100,000 DLG data has positional accuracies of 165 feet. The credibility of the DLG positional accuracies is sometimes questionable due to the age of the source materials used to compile the information. The SPOT imagery, after the appropriate triangulation and orthorectification processes, has a significantly higher metric accuracy than the 1:100,000 DLG, and a metric accuracy that approaches that of the 1:24,000 DLG to be developed in the future.

Temporal Accuracy

Temporal accuracy refers to the "timeliness" of the data. Is it out of date? How often is it updated? How difficult is the update process? The maintenance of map graphic data is often overlooked in building a GIS when indeed this is one of the most important issues in GIS operations. The development of digital data from 1:24,000 USGS quad sheets or using the USGS 1:100,000 DLG data the user should look closely at the temporal accuracy. Even when it is a newly developed digital data set, the temporal accuracy can be in question, due to the sources used. Many times the existing USGS data are no more recent than the late 1970's. The information has been photo revised in some areas.

SPOT imagery can realistically be retrieved rectified, and used to generate new map graphic data within a one to two month window. After the development of a large area multiple image mosaic, updates can be done to specific subset areas within the data set, within one or two months. For example, those areas in which the user knows there has been significant change can be clipped out of the existing SPOT mosaic map graphic data set and the new image data can be used to replace it. The end result is new imagery within old imagery, all rectified and mosaicked with no image edges detectable. The one to two month update time is dependant on atmospheric conditions and acquisition priorities, but even if maintenance images are only available every 6 months it is far more recent than the 5 or 10 year cycle commonly associated with aerial photo missions flown for map update purposes.

Feature Completeness Accuracy

Feature completeness is used in this context to define the amount of information contained in the map graphic data set. For image mosaics it is directly related to image resolution and for line graphic data it is related to the original compilation scale. Regional and local users will have different requirements for information content. This is a topic that creates a situation of weights and balances, based on the data handling capabilities of the geographic information system. Typically a vector data set over a specified area takes much less computer storage space than a raster image data set for the same given area. A vector digital map graphic data set is comprised of only selected features of interest, consequently only those features are available for the users applications. For the DLG databases that would include, transportation, hydrography, selected political/administrative boundaries, and contour lines. However if you have an raster image map graphic data set, you have a comprehensive view showing everything visible to the sensor for the given area. With SPOT imagery the information visible to the sensor equates to the 10 meter pixel resolution, so that anything smaller than 10 meters may not be detected by the sensor, unless it contains a significantly high tonal contrast with its surrounding area. For this reason SPOT imagery does not meet all of the needs of a local user group. However as discussed in the applications section of this paper, there are definitely uses for SPOT imagery for the local users in terms of query and location specific applications.

Feature identification is another important part of the feature completeness accuracy. Significant roads and buildings, along with all natural resource features such as lakes and forest areas, are easily recognizable on the SPOT images. Problem areas exist where vegetation covers roads or buildings. But this is a problem more significant to local users. There are also many situations where determining the significant shape of the building is not as important as knowing that it exists and its relative location. A large house for instance 60′ by 75′, will be reflected in 6 pixels making it easily identifiable in an image. A small house 30′ by 30′ will be reflected in 1 or 2 pixels, not significant in terms of identification, but allowing the user to see that there is indeed a building at that location. FIGURE 1 shows that many features on the image are quite easily detected, including many of the residential dwellings. As noted above it may not be possible to assign attributes to all those features.

The advantage of the DLG data is that each map graphic data item has already been selected, classified, and symbolized. With SPOT mosaics you do not have symbolized information. However, you do have a much more comprehensive view of the existing ground information which allows you to create your own feature identification and classification categories with information that is not present on the DLG map graphic data sets.

Accuracy Summary

To summarize the accuracy issues, each of these accuracy types relate to regional type databases or data sets that currently exist. TABLE 2 compares 1:100,000 USGS DLG data, 1:24,000 DLG data as it would be digitized from a USGS 7.5 minute quad sheet, and mosaicked SPOT imagery. The rectified SPOT image mosaic carries a higher metric accuracy than the 1:100,000 data, and approaches the metric accuracy of the 1:24,000 DLG potential. Also significant is that when you look at the effort involved in combining graphic data, such as multiple DLG files or multiple SPOT scenes, the differences in metric accuracy begin to look much more significant.

For temporal accuracies the SPOT imagery provides a much more useful solution. Not only can you get updated information in a relatively quick time frame, but you can develop an initial data set that is more up to date than the USGS DLG data. Unfortunately the 1:100,000 DLG data that exists today, in many cases is significantly out of date.

For feature completeness, the SPOT imagery is a comprehensive view of the existing ground information. The DLG data provides a data set in which selected features such as roads, waterways, and administration boundaries, along with topographic contours and names are identified for the user. For the user interested in only one or a combination of those features included in the DLG, it is a much easier data set to use. All of the information has been classified and symbolized. For users needing a comprehensive view of the area, the mosaicked SPOT imagery becomes an important map graphic database.

TABLE 2
DATABASE COMPARISONS

SOURCE	Positional Accuracy (feet)	Coverage Per map/image (sq. miles)	Maps or Images / Accuracy (sq. miles) 2500	125,000	250,000
SPOT	50	1400	2/50′	90/75′	180/100′
DLG 100	165	800	4/ns	156/ns	312/ns
DLG 24	40	50	50/ns	2500/ns	5000/ns

*ns = not specified

FIGURE 1: SPOT IMAGE DATA

SPOT satellite imagery, SPOT Image Corporation, Reston, Virginia, (C) CNES 1991

APPLICATIONS

The five most prominent uses for ortho-rectified SPOT satellite imagery on a regional level are:

- Geopositioning
- Reference Imagery
- Aerial Inventory
- Image Map Base
- Aerial Assessment

Geopositioning

One of the most essential parts of developing a sound GIS is the development of a georeferenced base. The control that goes into the base has a direct effect on all the other data layers that are developed for that area, both from the point of relative accuracies (feature to feature) and the ability for the analytical capabilities of GIS software to work properly. They will work regardless of the control, but results may be questionable or misconstrued if the control factor is not taken into account. The software used to orthorectify the image can maintain the control values used, as an attribute of the locational pointer on the data image. This allows the users to directly compute and display geopositional values for any location on the image.

Image Map Base

The very aspects that make the SPOT image a good geopositional source also make a very valuable image source for digitization of graphic vector information. Anything that can be viewed on the image can be digitized through "heads up" digitizing techniques. Because the information is taken directly from the image, and the image is geopositionally accurate, the new vector can be compiled using the exact same georeferenced data. Because of existing raster/vector integration capabilities on most GIS software packages, SPOT imagery may be used for vector data development and more importantly vector data maintenance, for regional GIS users.

Reference Imagery

For regional or local users that have developed or are developing a large scale data set, the SPOT image can serve as a reference layer. Most mapping departments or offices that make use of large scale maps on a regular basis, have an overview reference map that allows them to determine which specific large scale map or map file they want to use to study or solve a specific problem. In current GIS systems if the data base has been constructed from large scale source it usually requires a significant amount of computer storage. It may take a great amount of time to search or "view" the entire database to determine which specific area is needed. Using an overlay grid and the SPOT mosaic image as a reference, the user can access specific large scale areas of interest.

Aerial Assessment

Aerial assessment encompasses the specific activities that decision makers are dependent on during the planning, implementation, and maintenance of a major capital project. A utility company wanting to determine the best corridors for new transmission lines, or a coal company wanting to assess the impact area for a defined coal source, can make use of current imagery. Mosaicked SPOT satellite imagery provides an easily attainable data source for assessing physical and economic changes that have taken place after major engineering projects. Satellite imagery can be very beneficial in the data maintenance and on going assessment of areas of concern. SPOT mosaics can also be used as a means of defining the exact localized areas for large scale analysis.

Aerial Inventory

Aerial inventory involves the categorizing and quantifying of the natural resources such as forest areas, mineral and energy sources, wetlands, agricultural lands. Natural resource areas may change yearly, and therefore the data and its functionality is quite dependant on timely and easy updates. Because orthorectified SPOT image mosaics can be developed within a one to two month time span, they provide the capabilities to quickly re-inventory areas for changes due to human interventions, natural disasters, or climatic changes. Also of significance is the "comprehensive view" that you get with the SPOT data. Instead of only selected features being shown, you see all natural features (on the ground) as they appear in real life.

CONCLUSION

Regional users can benefit greatly from the information contained in the satellite imagery currently available. The images are relatively easy to attain, and with current software capabilities SPOT image mosaics can achieve positional accuracies that approach those associated with USGS 1:24,000 7.5 minute quads (used extensively by local users) and are much more current and easier to maintain than the equivalent digital data created from the USGS products. The SPOT image mosaic data sets have metric and temporal accuracies that significantly exceed those of an existing 1:100,000 DLG vector "off the shelf" data set. In all likelihood the SPOT imagery will be used as a primary update source to the newly developed 1:24,000 DLG data when it becomes available. For feature completeness the significant benefit of the SPOT mosaic imagery is the real "view" of the area that they provide.

The initial costs of image data bases may be significantly greater than for public domain DLG. These costs must be amortized by GIS operational savings which may sometimes be difficult to quantify. The currency, completeness, and positional accuracies coupled with the potential for automated extraction of GIS significant features from the image mosaic, as well as the ability to use existing DLG and SPOT imagery simultaneously, are all factors which can justify the initial expenditures. Careful analysis of all these factors will determine the cost effectiveness of SPOT image mosaic for individual local and regional users.

Providing the GIS users with seamless views of orthorectified imagery, and with newly developing vector integration techniques, users can address many of the current problems associated to vector data updates. In the near future many users will purchase specific available data bases to address the needs of the organization, and when there is a need for highly accurate data, or very unique data, it will be developed in coordination with that common database, in a slower, more methodical and more project driven manner. Future launches of commercial satellite imaging systems will insure the continued use of this image data for the production and maintenance of map graphic data bases for regional GIS applications.