INPUT PROCEDURES FOR TM-LANDSAT PHOTOGRAPHIC PRODUCTS INTO A GIS ENVIRONMENT

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ABSTRACT

Visual interpretation of high-resolution images is an important tool because digital processing techniques do not completely replace the human capacity of understanding spatial features over an image. System corrected images present internal geometries that are compatible to medium scale works, but photographic processing can introduce small-scale changes for the whole image. Therefore, a sequence of heuristic local adjustments is usually carried out by interpreters with the purpose of transferring image information onto the topographic map that represents the GIS database. As a consequence, the resulting thematic database is badly georeferenced. This work presents two alternatives, which were used for the georeferencing of TM-LANDSAT photographic products intended to detect and control the deforestation process over the Brazilian Amazon.

Key words: GIS/LIS, Image Interpretation, Image Matching

Introduction

Geodetic Accuracy of TM-LANDSAT imagery

System corrected TM-LANDSAT pictures still represent basic products for various environmental research projects. Although fully corrected images are preferable, they are not so widely used for visual interpretation mainly due to their processing costs. Instead of using them, it is less expensive and more common to use system corrected ones. Many studies were presented in the last two decades showing geometric correction procedures and the results of geometric evaluations over LANDSAT images.

Welch, Jordan, and Ehlers (1985) presented a geometric evaluation of system corrected digital TM data. Internal accuracy of around 30m was obtained using ground control points extracted from large-scale maps. They emphasized the need of having image coordinates of control points within 1 pixel of accuracy.

Machado e Silva and d'Alge (1986) showed slightly different results – 40m – for the internal accuracy in a similar geometric evaluation procedure over 1:1,000,000 TM diapositives. This discrepancy could be explained by less accurate image coordinates. It was not possible to ensure 1 pixel of accuracy for control points determined over those photographic products.

Similar geometric evaluation reports were presented by Borgeson, Batson, and Kiefer (1985) and by d'Alge (1987). All these works comment, in some extent, on the influence of control point accuracy on geometric correction models and geometric evaluation results, and also agree that 1:100,000 must be considered the largest scale for the use of TM images.

Besides this fact, there is an important source of errors that can easily affect the geometry of a photographic product. Successive enlargements performed by precise photographic equipment must not introduce local distortions, but can originate a general scale discrepancy. Therefore, the photointerpreter will probably deal with some small matching problems while trying to perfectly register the whole scene over a cartographic base. For example, the base is a

1:250,000 scale map and the interpreter has a 1:248,600 scale image. This work assumes this hypothesis, discusses the conventional approach for visual interpretation, and presents alternatives aiming at an accurate input of image content into a GIS database.

Conventional photointerpretation procedures

It is convenient to explain what is meant here as conventional photointerpretation. Photointerpretation means a set of procedures that represent the human capacity of understanding and extracting features from an analog image. The term 'conventional' carries the meaning of absence of GIS or computer cartography technologies. In other words: a cartographer receives a paper overlay with image features and has to design and draw a map manually.

A typical working session is assumed as an example. Suppose a forest engineer is interested in mapping the extension of deforestation in a national park which appears entirely on a 1:250,000 topographic map and consider the existence of a nominal 1:250,000 TM-LANDSAT color composite covering the park. In the first step map corners and basic features such as rivers and roads are transferred to a transparent paper sheet (overlay). Next, this overlay is superimposed over the image and registered by means of common rivers and roads. The interpreter then starts the procedure of extracting and drawing what is of interest. This situation requires the image and the map to have the same map projection. Moreover, the image must be precisely at 1:250,000.

Unfortunately this condition is rarely achieved. The interpreter can not perform a precise matching between image and map. The traditional solution for this problem is the use of local adjustments. The more image scale differs from 1:250,000, the larger is the number of required local adjustments. Although this method is a valid procedure under the absence of GIS or computer cartography facilities, its basic characteristic is the subjectivity in defining the sequence and number of local adjustments. It is impossible for a second interpreter to perform exactly the same registration between image and map.

Conflict with an accurate GIS database

The idea of accuracy in a GIS database is strongly related to the capability of evaluating errors in every step of the current processing. This means, for instance, that the lineage of a map has to be known in order to estimate its accuracy. If map inconsistencies and their sources are known, it will be feasible to use a mathematical model to correct them.

The digitizing of a map can be use as a good example in this discussion. One operation that precedes (or follows, depending on the system) digitizing is the establishment of the relation between map and digitizing table coordinates. An affine transformation is usually used for this purpose (Burrough, 1986). This function also acts as a reliable model to correct map errors, in case these errors represent the effects of rotations, translations, and scale changes. But who knows the result of applying such model over a map without lineage documentation? How does an affine function act over that overlay produced by successive subjective local adjustments? It is very difficult to get a reasonable answer. One can just believe that everything is correct.

This is the basic conflict. An overlay produced by the conventional photointerpretation technique can not be perfectly modeled by any algorithm, because it is impossible to represent by mathematical functions all those heuristic adjustments the interpreter made. Then it is very hard to assess the accuracy of the resulting digitizing data. If the idea is to produce an accurate GIS database, one must avoid generating that kind of overlay as an input data source.

Proposed methodologies

Amazonia deforestation database

The Amazonia deforestation database is a project carried out by INPE that contains full information on the deforestation process for the years 1975, 78, 85, 88, 89, 90, and 91. Legal Amazonia' as defined by the Brazilian

Constitution, 1988, includes the states of Acre, Amapá, Maranhão (west of 44°W), Amazonas, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins.

LANDSAT images have been used as a basis for monitoring each deforested area. The database, comprised of 1:250,000 map sheets, is organized in blocks of 1° of latitude by 1.5° of longitude. These blocks are individual projects for purposes of data digitizing, analysis, and plotting of maps. Besides the 1:250,000 map sheet partition, the study area can be subdivided in different non-overlapping cells that cover the whole area (Meira Filho, 1991):

- subdivision by state;
- subdivision by municipality;
- subdivision by nominal LANDSAT 4/5 scene;
- subdivision by nominal LANDSAT 1/2/3 scene;
- subdivision by vegetation classes.

The database was constructed using SGI, a geographic information system developed in the Image Processing Division of INPE, which runs on IBM-PC compatible microcomputers. Some new functions were added to the basic software to improve error controlling and to provide faster processing. An example is the automatic definition of nominal LANDSAT cells given a 1:250,000 map sheet (intersection of two different subdivisions). Figure 1 shows a typical intersection between nominal LANDSAT scenes and a 1:250,000 map sheet.

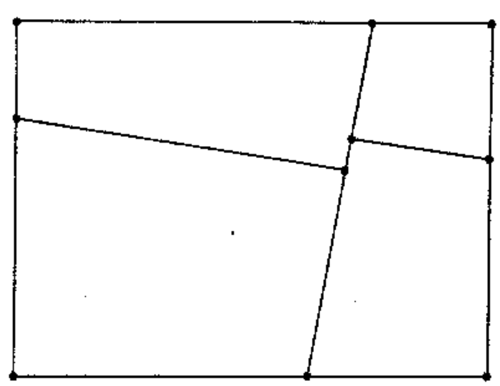

Figure 1 – Nominal LANDSAT cells

The automatic definition of the nominal LANDSAT cells is followed by a polygon overlay operation that takes into account the subdivision by states. The resulting infolayer contains the so called basic cells, as shown in figure 2.

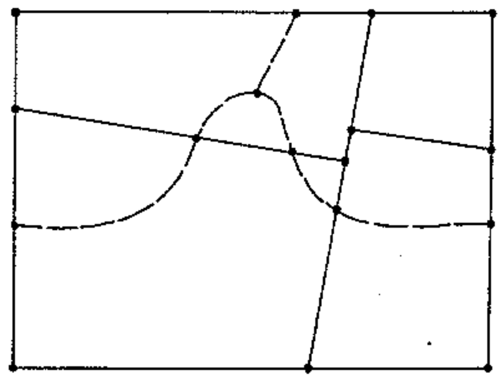

Figure 2 – Basic cells

Thematic information extracted from LANDSAT images – forest physiognomy, anthropogenic action, and cloud cover – is recorded within each map sheet for each basic cell. The date of the image is assigned as an attribute for both anthropogenic action and cloud cover, because they are time-dependent parameters. The analysis of the LANDSAT images in conjunction with the vegetation map of Brazil allowed the separation of four classes of forest physiognomy: primary forest, secondary forest, non-forest, and water bodies (Meira Filho, 1991).

As described before, the conventional photointerpretation approach was considered unfit regarding an accurate insertion in the database of the information extracted from LANDSAT images. Both methods #1 and #2, whose descriptions follow, are based on the same alternative photointerpretation procedure. The method consists in avoiding that first conventional step of transferring map corners, rivers, and roads from map to overlay prior to image content extraction. The interpreter acts directly over the image without any information from the cartographic base. Besides the basic information (anthropogenic action, forest physiognomy, and cloud cover), rivers and roads are also extracted from the image. These features provide the control points that are used by methods #1 and #2. The idea is to produce an overlay that is a perfect copy of the image in terms of geometry, allowing the modeling of image content through an affine transformation during digitizing.

Method #1

Method #1 can be considered as a 'direct' input of image content (overlay) into the 1:250,000 map sheet projects. The process starts with an approximate subdivision of the whole overlay by map sheets, as shown in figure 3.

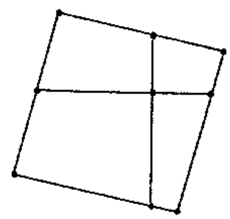

Figure 3 – Overlay divided by map sheets

This approximate partition is carried out by a different group than that of photointerpreters and has the objective of selecting road intersections and river confluences for control points. This method requires a minimum set of four control points for each individual subdivision. This number of control points represents the minimum requirement to produce a least square estimation of the parameters of an affine transformation. The existence of one set of control points for each subdivision explains why the method is called 'direct'. Each subdivision of the overlay is mapped directly into the corresponding map sheet project, as illustrated in figure 4.

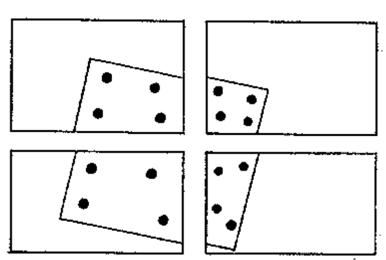

Figure 4 – Direct mapping with different sets of control points

As this method deals with approximate subdivisions, overlay data are digitized exceeding the boundaries of the cells that they are mapped into. The last step is then an automatic clipping procedure to determine all intersections between lines and cell boundaries (nodes) and to delete exceeding arcs. Figure 5 shows this situation.

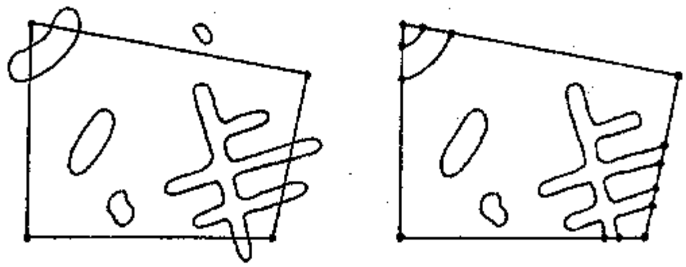

Figure 5 – Clipping procedure

Method #2

Method #2 is a variation of the first one and can considered as an 'indirect' method. Instead of using different sets of control points, only one set is required for the whole image overlay. Again, due to least square estimation of parameters, a minimum set of four control points is required. The entire overlay is digitized and stored in a temporary file, which is further use for the transference of data into the map sheet projects. Therefore, the method is called 'indirect'. Figure 6 illustrates the situation of control points in this method.

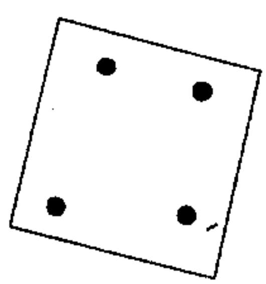

Figure 6 – Indirect method and control points

Overlay data are stored in the temporary file in terms of digitizing table coordinates (e. g., mm) and are mapped into each map sheet project by means of the geodetic coordinates of the control points through an affine transformation. The last step in this method is also the clipping procedure previously described.

Comparison between methods

The first important discussion is associated with the number of required control points. Method #1 is totally dependent on the intersections between the nominal LANDSAT WRS grid and the 1:250,000 map sheet partition. Hence it makes use of a large number of control points, amounting to a minimum of 16 in the example of figure 4. This requirement is difficult (impossible in most situations) to achieve in some regions of the Amazon. Sometimes the task of finding control points is not feasible because some nominal LANDSAT cells are too small. Method #2 only needs one set of control points for the whole image. It is then more suitable for regions where it is difficult to identify control points.

As the Amazonia database is organized by 1:250,000 map sheet projects, method #1 is more straightforward for the digitizer, who reasons to finish the current project before starting another one. People who worked as digitizers were reluctant to adopt method #2. They preferred method #1 and used method #2 only for regions with few control points.

Method #2 provides digital copies for all image overlays produced by photointerpretation, allowing different groups to work on the insertion of image information into the database. This is not possible with method #1, because paper overlays must be used.

Conclusion

Both methods produced accurate results and are more suitable than the conventional procedure, but method #2 provides a better organization of the tasks involved. Moreover, it has the advantage of requiring just one set of control points for the entire image.

The idea of using these alternative procedures is strongly related to the purpose of creating an accurate database including deforestation extent. Methods presented in this paper are to be considered as part of current efforts in two important GIS research topics: accuracy of spatial databases and integration between remote sensing and GIS.

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