DIGITAL MAPPING FOR CADASTRAL PURPOSES

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ABSTRACT

Current trend in Central American local governments is the use of digital mapping for cadastral purposes in the context of Geographical Information Systems, GIS. Having small, complex and weak economies, Central American countries are increasingly relying on modern mapping technologies in order to achieve efficient property taxation. Since late 80's, Costa Rica has been investing in this issue using its own resources as well as resources obtained from international aid in form of low interests loans and donations. From the technical point of view, efforts have been made from ground based techniques to the use of digital photogrammetric remotely sensed imagery. Also, the country benefits from the acquisition of remotely sensed data within the Carta Mission Program. However, the products obtained are combined with other kind of spatial data acquired by means of traditional methods. This work addresses the difficulties and unsolved issues raised during the data integrating processes along with recent changes in datum and cartographic projections in the country, and prevailing paradigms. Several projects carried out at local government level are discussed. Three national cadastral programs are reviewed. It is evident that elevation data is becoming an important variable for municipalities in different projects. By the end, possible trends of the modern mapping techniques are presented.

Keywords: Global Positioning Systems, Digital Photogrammetry, Geographical Information Systems

INTRODUCTION

Costa Rica is the Central American country located between Nicaragua at the northwest and Panama at the east. The country has coasts in the Caribbean Sea and the Pacific Ocean. Most of the population is concentrated at the Central Valley that is surrounded by high mountains and volcanoes. Tourism is one of the major economic activities and landownership has developed rapidly during the last two decades regarding suitable locations for this activity. As occurred all over the world, landownership has produced conflicts among the country's inhabitants. Sometimes, conflicts had its origins in government policies to protect wild life ecosystems and other had its origins on a weak land ownership registration.

During the early 70's, the German Technical Mission established links with the Costa Rican government to strengthen the National Cadastral Institute in Costa Rica as well as other Central American cadastral entities. The aid included training Central American and Caribbean citizens in land surveying for cadastral purposes throughout higher education in Costa Rica and in the former Federal Germany.

EARLY CADASTRAL MAPPING

At the beginning of the 80's, the Costa Rican National Cadastral Institute, started to elaborate the cadastral maps at the 1:1 000 and 1:10 000 scales for urban and rural areas respectively. Based on conventional geodetic surveying, analog aero triangulation and photogrammetric techniques, cadastral maps were constructed using photogrammetric maps, field work and existing land surveyed plans.

The land surveyed plans, called locally “cadastral plans” are prepared by licensed land surveyors at varying scales defined according to the law established in 1981. Based on the numerical data describing the parcel limits, cadastral plans with different scales were redrawn in translucent paper and mosaicked on the preliminary cadastral map were the parcel blocks were previously drawn.

Parcels in cadastral maps were numbered in “streamer” form, using parcel numbers, an attributive analog table was build up to complete landownership data. This table was written manually on a page of a register book called the “cadastral index”.

It is important to recall that by the time, computers did not manage spatial data linked with literal information for landownership maps. Software and hardware to establish geographical information systems were in an early development stage and operational systems were expensive. Personal computers were being developed and unfortunately, it cannot deal with huge amount of data as is the case with landownership maps.

Maintenance of this analog landownership system had several logistic problems. Graphical data updating was time consuming and the management of attributive data was also complicated when properties were physically modified by splitting and merging. These changes involved changes in the attributive data as well. No elevation data was considered at the time.

Landownership information was managed at local government level mainly in literal form. Cadastral maps copies were also used, but due to logistics problems as well as budget limitations, parcel updating was given up when the amount of work exceeded personnel capabilities.

THE DAWN OF DIGITAL CADASTRAL MAPPING

Beginning the 90’s The Netherlands supported a national cadastral updating program within the “Technical-Economic Cooperation Agreement for the Improvement Program of the National Cadastre – Multipurpose Cadastre, between the Government of the Republic of Costa Rica and the Ministry for Development Cooperation, Kingdom of the Netherlands”.

Preliminary studies for setting up this program were carried out since year 1988 (Dörries, E. et al, 1992). Geodetic ground control was established using Global Position Systems GPS, receptors. GPS observations gathered during the CorBas 1990 project were also considered within this program.

The CorBas 1990 project aimed the construction of a new geodetic network in Costa Rica to perform not only geodetic but also geodynamic studies to investigate tectonic movements and regional movements of the earth's crust (Niemeier, W. & Aguilar, L., 1990).

GPS observations were carried out upon existing geodetic points established by the Inter American Geodetic Survey during the 1940 and 1950 decades. As a result, coordinate transformation could be performed using polynomial approximations, instead of the rigorous formulae application from the mathematical geodesy.

Dörries suggested the change of datum and projection to achieve a unique cartographic system for the whole country. All the basic and derived cartography was based upon two Secant Lambert Conic Conformal Projections, namely Lambert Costa Rica North LCRN, and Lambert Costa Rica South LCRS, (IAGS, 1950).

The proposed system was the Universal Transverse Mercator (UTM) modified for Costa Rica. Costa Rica is located between UTM zones 16 and 17, with central meridians at 81° W and 87° W respectively. As a result, using UTM coordinates will mean having two coordinate systems again. The proposed system uses a central meridian at 84° W, and the WGS84 ellipsoid as the theoretical horizontal datum and the mean sea level as the theoretical vertical datum. Factor scale at central meridian is 0.9996 (Dörries, E. et al, 1992).

To realize the datum, GPS observations were processed then the Costa Rica Transversal Mercator year 1990, or for short CRTM90, was established. This system was adopted by the National Cadastre despite the National Geographic Institute remained using the LCRN and LCRS cartographic systems.

The products obtained within the Dutch were the photogrammetric maps and the maps depicting the limits between individual properties. In digital form, the maps used linear entities, polygons were not used. This cartography uses the CRTM90 cartographic system. Elevation data was not considered in these products.

THE TERRA COMMITTEE AND THE NEW CARTOGRAPHIC SYSTEM CRTM98

On July 1995, the Costa Rican government published in the official newspaper the Terra Committee establishment. This project aimed to order the country's territory but the information and data was overwhelming, highly segmented, in different formats, scales, and cartographic coordinate systems (CONICIT, 2009).

To develop the mapping tasks, an international company was hired. In April 22 1991, a 7.1 Richter's scale earthquake took place in southern Costa Rica and North West Panama. This severe earthquake provoked the raising of the Caribbean coast line in the region.

As a result, the geodetic control points that realized the CRTM90 datum were moved in a way that new GPS campaigns were needed to realize the datum again. These GPS campaigns allowed the establishment of the CRTM98 datum.

The new cartographic products obtained by the Terra Project, in charge of the Terra Committee, are in this new coordinate system. The Costa Rican National Cadastre stated that all new cadastral projects developed by local governments should use the CRTM98 cartographic system.

THE MUNICIPALITY OF SAN JOSE CADASTRAL PROJECT

In 1992, the former Urban Information Section depending on the Urbanism Directorate hired a private company to digitize the existing cadastral maps at scale 1:1000 for the Central Canton of San Jose.

The digitized maps were joined together and the digital parcel map of the Central Canton was obtained, attributive data included were the numbers corresponding to the map consecutive identification, the parcel number, and a number depicting if the parcel was a part of a larger property.

Since literal data for parcels is managed by a proprietary computing system, attributive data was obtained in ASCII format, and linked to the parcel digital map using the above numbers as keys.

In 1997, personnel of the former Cadastral Development Department, based on the experience of the USI-UD, realized that digital landownership maps and data should be updated from scrap. This department was using by the time the digital parcel map previously obtained by the USI-UD.

After the required authorizations by the Council and the National Cadastre, budget approval and related procedures, the Cadastral Updating Project was assigned to a private company. The project officially started on February 5, 2002.

For this project, ground control point as well as aerial photography acquisition was required. GPS observations on National Cadastral geodetic points were carried out and a network of 270 GPS surveyed points was established. In the terms of reference, height data was included in form of a Digital elevation Model DEM, to support further analysis for Municipality's needs.

However, there were some difficulties when linking GPS surveying to the Costa Rican vertical network. Identical points should accomplish certain conditions: an appropriate quantity and adequate positioning to obtain geometrical rigidity and strength. The quadrilateral plotted with external identical points should approximate a parallelogram, and depending on the study area extents the quantity of such linking points varies (Trimble Navigation Limited, 1991).

Proposed configuration of this linking network is depicted in Figure 1. However, due to failure in finding some of the chosen ground control points established by the National Cadastre, the final configuration has an ill conditioned configuration as presented in Figure 2. Figure 3 shows both configurations.

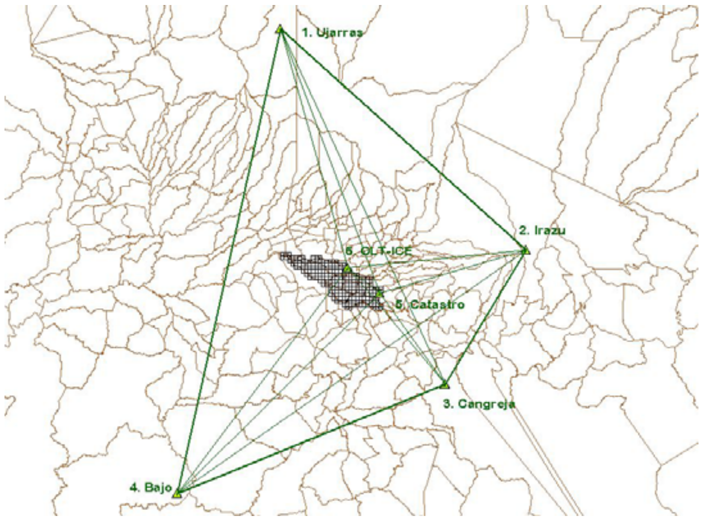

Figure 1. Proposed configuration for the identical points locations. Study area is enhanced with the cadastral maps outlines. Gray lines correspond to district limits.

Due to this fact, personnel from the National Cadastre found that eastern parts of the study area had significant differences in height for some of its benchmarks. These differences exceeded the tolerances established by this institution. In order to correct height coordinates for ground control points, GPS observations previously obtained by the National Cadastre and its counterparts recorded by the hired company were combined.

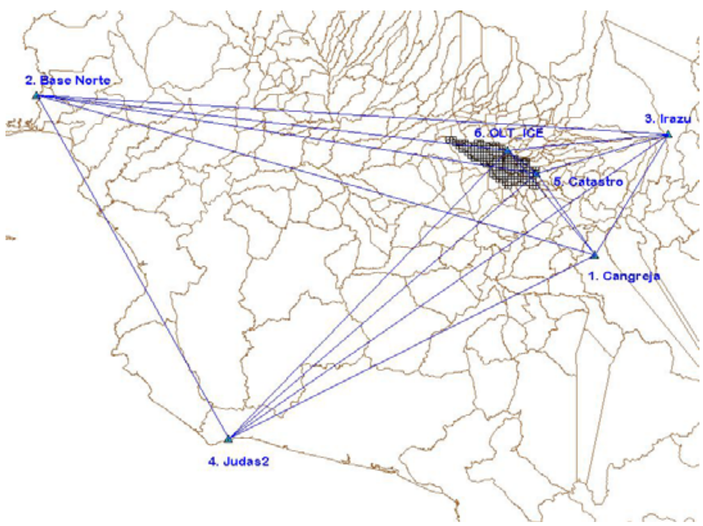

Figure 2. Final configuration for the identical points locations. Study area is enhanced with the cadastral maps outlines. Gray lines correspond to district limits. The Pacific Ocean shoreline is shown at the bottom left.

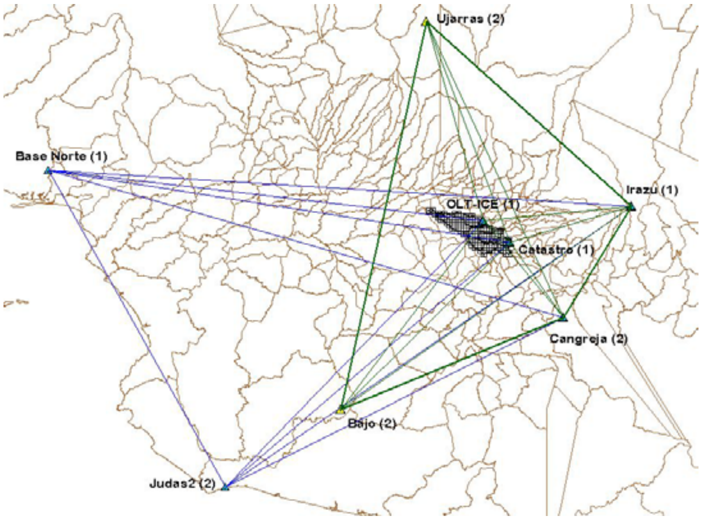

Figure 3. Proposed versus final configuration for the identical points' locations. Study area is enhanced with the cadastral maps outlines. Gray lines correspond to district limits. The Pacific Ocean shoreline is shown at the bottom left.

This combination rendered heights with mean square root errors within established tolerances. A comparison between the uncorrected height values and the corrected ones was performed using the market's leading geoprocessing software for personal computers. The results are shown in Figure 4.

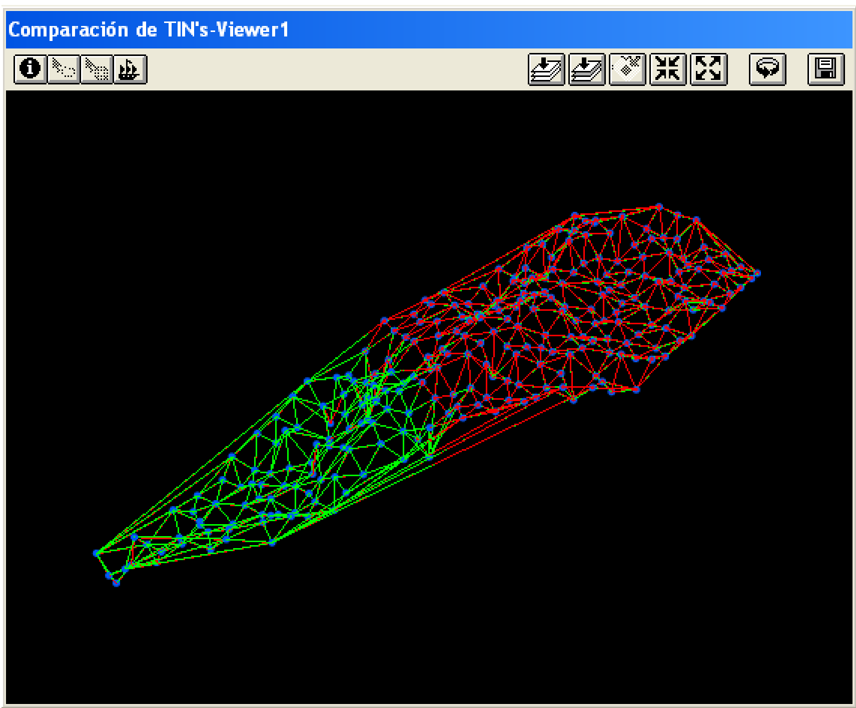

Figure 4. Triangular irregular networks for the ground control points established with GPS observations and linked to the National Cadastre vertical network. In red, the obtained results within the cadastral project. In green, the triangular irregular network corresponding to the corrected height values.

Unfortunately for the Municipality of San José, height values associated with contour lines were not corrected in the photogrammetric maps. Also, the DEM were not produced according with the contract's terms of reference.

Until now, the project still lacking of its “technical closure”, and administrative procedures are being implemented in order to achieve contract’s fulfillment.

As needed for daily work at the Municipality of San José, the photogrammetric maps obtained were joined in a preliminary data base using software for GIS. There were data sets in different coordinate systems. All of them were transformed into the CRTM98 cartographic system.

When over imposed, data sets show noticeable positional differences. These positional differences are due the uncertainty of the translations, rotations and scale factor of the WGS84 ellipsoid with respect to the Clarke 1866 ellipsoid, and also due to the differences in the realization of the CRTM90 and CRTM98 datums, among other reasons (Dörries E. & Roldán, J., 1999). These differences are shown in Figure 5.

Combined data originally were in the LCRN, the CRTM90 and the CRTM98 coordinate systems. The first is based on the Clarke 1866 ellipsoid and the other two in the WGS84 ellipsoid. For the first data set ground control point were established with traditional surveying methods and maps were constructed based on analog aero triangulation and manual parcel drawing. The CRTM90 data set was obtained using GPS observations with equipment produced with the best technology by the time, and photogrammetric maps were produced using analytic photogrammetry. CRTM98 data set were obtained with GPS observation with equipment with better performance and smaller sizes than the ones used for the CRTM90 data set production, and analytic/digital photogrammetry.

It can be question which of the data set is the correct one. The answer is that all of them are correct positionally, since they were prepared with different technologies, the best at the time of its production.

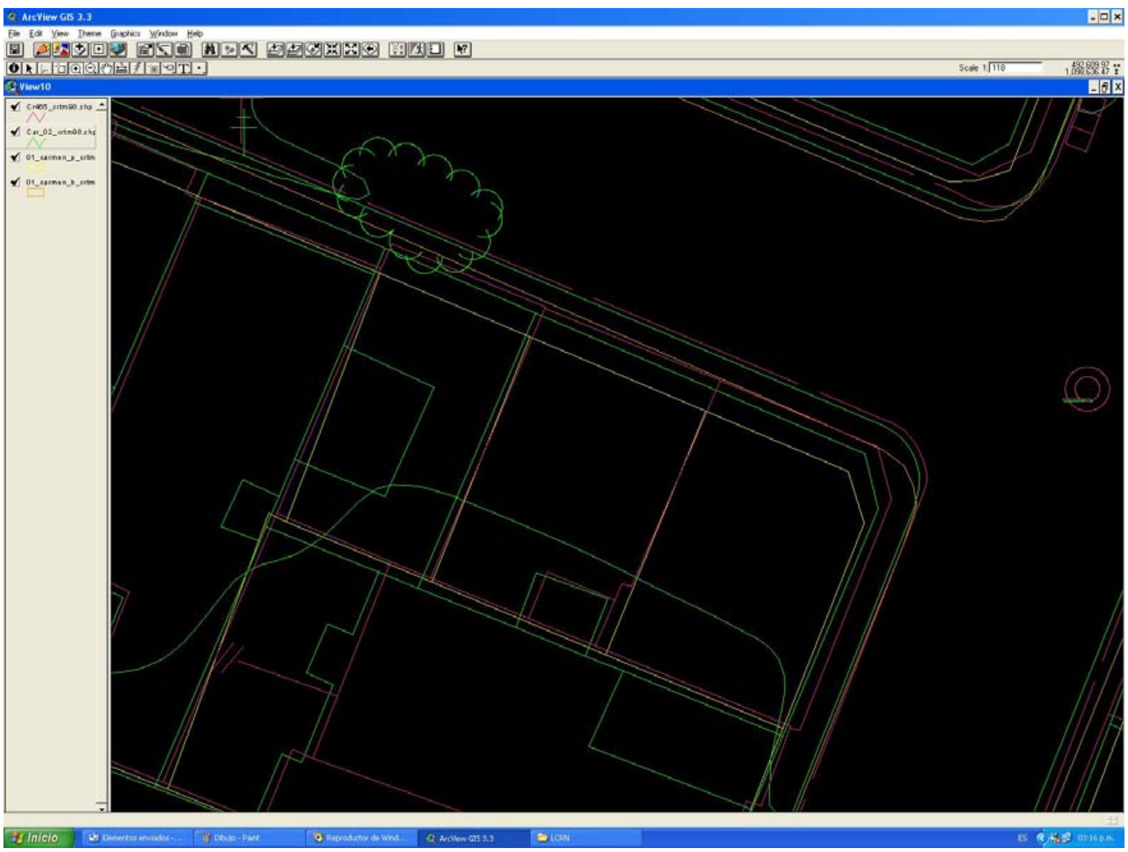

Figure 5. Parcel map originally in the LCRN cartographic system is in yellow. In magenta, the photogrammetric map originally prepared in the CRTM90 coordinates system. Green is used for the photogrammetric map prepared in the CRTM98 coordinates system. The first two maps were transformed to the CRTM98 coordinates system.

THE SANTA ANA CADASTRAL PROJECT

Santa Ana is a canton in the San José province. For updating its landownership maps, this municipality decided to develop an aerial survey using a digital photogrammetric sensor, but used the leading market's CAD software, instead of suitable software for GIS establishment.

The obtained imagery was orthorectified using ground control point based on GPS observations. The orthorectified imagery was segmented in map quadrants for easy use. Currently, personnel of this municipality are gathering landownership attributive data in the field and throughout property declarations for taxation.

Figure 6 show a zoomed image of an urban area in this Canton. This image is uncorrected.

Figure 6. Image detail of a residential area in the Santa Ana canton obtained with a digital photogrammetric sensor. The image is uncorrected.

THE COSTA RICAN LAND REGISTRY PROJECT FINANCED BY THE IDB

As mentioned in the introduction section, landownership has produced conflicts in the country. To guarantee landownership, the Costa Rican government is developing a National Cadastral Program partially funded by the International Development Bank, IDB.

Details about the advancement of this program can be found at the Internet site http://www.uecatastro.org. Regarding this article, it should be mentioned that the cartographic system has been modified again. CRTM98 users claimed that the system had inaccuracies when determining point coordinates in areas far from the central meridian.

To compensate these differences, the theoretical horizontal datum was modified, changing the scale factor at the central meridian to the value 0.9999 instead of the previous value of 0.9996. With this new factor scale variations in the mentioned areas are reduced. With this new scale factor, the secant ellipsoid will be closer to the Earth's surface and therefore cartographic representation would better approximate the landscape.

Much of the field work is to be executed, and for this reason an extension for the program has been recently approved. It is expected that with a successful conclusion of the program, landownership problems won't be severe and hard to solve.

Aerial photography acquired in the Mission Carta program has been acquired for the whole country at different scales to build up the cadastral maps for urban and rural areas. Information regarding this program can be found at the Internet site http://bocachica.arc.nasa.gov/CARTA_2005.

TRENDS IN CADASTRAL ISSUES

In the Central American region, the trends are increasingly relying in using high technologies to manage landownership data. These trends involve the use of the GPS technologies, digital photogrammetry, orthorectified remotely sensed imagery and the integration of data and information within the context of corporate Geographical Information Systems. Local governments are interested in managing property taxation using GIS to improve their income and consequently providing better services and improving amenities in urban areas.

CONCLUSIONS

1. In developing countries, landownership can be guaranteed by efficient cadastral systems
2. The use of recent digital imagery at different resolutions is recommended
3. As a minimum, imagery has to be acquired every five years
4. Cadastral systems need to be updated by several means, but field work should be the priority
5. Spatial information must be standardized to the most recent coordinates system
6. Geodetic points should be maintained and for this task, proper budget must be assigned and not diverted
7. To handle landownership maps, Geographical Information Systems software must be used instead of CAD software
8. An adequate Geoid Model should be constructed to convert with confidence ellipsoidal heights into orthometric heights
9. Personnel professionalization of the involved organizations in cadastral projects should be pursued throughout higher education
10. Efficient supervision of works regarding cadastral projects should be encouraged

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