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Automated Rectification of Vector Parcels & planimetrics to Raster Imagery – No Rubber sheeting

Authors' names

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Paper Abstract

Traditional vector rectification technology has produced unsatisfactory results as data integrity was distorted through rubber sheeting processes along with prohibiting consistent adjustment of associated annotation. An intelligent automated technique is now available, producing rigorous and repeatable results in bringing disparate vector layers (and associated annotation) synchronous and aligned to higher accuracy ortho-imagery improving spatial integrity while adhering to ground control constraints and apparent occupation. The resounding success of the first U.S. commercial application in Jefferson County Colorado is presented and demonstrated. The result is more reliable, accurate, faster, credible, and usable GIS data.

Paper Body

I. Overview

Jefferson County, Colorado holds its county seat in Golden and includes 33 full or partial Townships covering 770 square miles with 220,000 parcels and is surrounded by some of the most severely diverse terrain and ground cover found anywhere. Terrain conditions from flat plains to Rocky Mountain Front Range are found here. Extreme elevation changes and historical monumentation mistakes added additional error in the existing data layers, creating additional obstacles in the rectification process not capable of being addressed by Rubber-Sheeting techniques.

II. The Problem

In 1995 Jefferson County decided to convert its paper based/hand drawn parcel maps to a digital ESRI format. IT-Development worked closely with the Assessor's Office to get this project done with a very limited budget. These paper Assessor maps were built at a variety of scales and quality. In addition few of the paper maps completely edge mapped. This work was done by an overseas contract with little knowledge of American land law. The resulting product needed another 5 years of work by the Assessor's office to become

a truly useful data layer. New edits and additions were often COGO'd and best-fit edits were conducted to deal with problem areas. Imagery from multiple years was used as a reference layer. A large and expensive effort to capture all the significant annotation off the old paper maps was conducted so that the paper maps could be completely retired. The end product of this multi-year effort was quality digital maps, which eliminated the need for paper and hand editing.

In 2002 we acquired high quality, 1-foot pixel imagery of the entire County through a regional consortium. This imagery constituted a standard base to be used by not only Jefferson County but the adjacent counties and cities as well. As is the usual case the parcel did not line up with this new imagery (figure 1). This lack of spatial integrity visually called into question the accuracy of the parcel layer especially in public hearings and made the parcel layer less likely other agencies would adopt this data as their standard. Additionally, the County wanted to use the parcel layer as the basis for all geopolitical boundaries such as precincts, zoning, special districts, city boundaries and for the calculation of parcel area when this area was not available in the recorded deed.



Figure 1. Original unrectified parcels on 1996, 1 meter aerial imagery

The task was enormous. Hand editing of the digital data would take years, and COGO entry would take even longer. Many of the legal descriptions were poor and multiple monuments existed at critical section corners. Enhanced rubber sheeting was evaluated

and rejected as the required shifts varied from parcel to parcel and never followed any particular direction. In addition it was critical that rectilinear orientation of the parcels be maintained (North –South lines had to stay North-South). Parcel area and orientation had to be maintained as much as possible. None of the 350,000 assessor annotations were linked to their parent parcels (including tie bars). All would have to be moved.

The existing parcel data along with the rest of the Counties many data layers had to be rectified to the imagery to be of real value to decision-makers. The County had spent millions to build these layers but it appeared we would have to spend millions more to resolve our problem.

In 2002 a firm, Pixxures Incorporated, claimed to have solved the problem. A number of samples of County data were sent for evaluation. The new technology had the ability to move any feature to any fixed point on the imagery while preserving the character of the parcel and it's surrounding parcels. Often this mean using apparent occupation (fence lines, roads etc), yet the section corner monumentation had to be honored, a seemingly impossible task. Early results were very promising. Correctly moving the annotation was the next big step. A funded prototype program was established to test the concepts. The results were very impressive (figure 2). The vast majority of parcels and annotation could be rectified to the imagery base. Contracts were approved and the Jefferson County GIS Rectification Project was set up to rectify the parcels and a host of other data layers.



Figure 2. Unrectified parcels in red, Rectified parcels in blue on 2002 aerial imagery

disparate data themes for the entire County into synchronization to enable a final

adjustment of all themes to fit the recently acquired 1-foot ground sample distance (GSD) 2002 Ortho-imagery base. (Currently being updated in 2004 at the same resolution.)

The data layers to be synchronized then adjusted to fit the raster imagery include:

- a. Cadastral Parcels & Associated Annotation
- b. Subdivisions
- c. Hydrology
- d. Zoning
- e. FEMA Flood Plains
- f. Addresses
- g. Land Use Inventory
- h. Political Districts
- i. Streets & Roads
- j. Fire Fuel Model
- k. Special Districts
- l. Geologic Hazards
- m. Open Space Parks/Trails
- n. Hazardous Waste Sites
- o. Water Treatment Sites

III. Data Format

- a. Data currently resides as coverage's in ArcInfo
- b. Current data themes registered to Raster Imagery based on:
 - 1996 1-meter Aerial Ortho-imagery
 - 2001 1-meter Satellite Imagery
- c. Provided to Pixxures as e00 files covering townships
- d. Total number of parcels (220,000)
- e. Controls provided:
 - GPS Survey control for 85% of section corners
 - Balance of section corners from DLG projections or other sources
 - All other control derived from ortho-imagery produced by Pixxures at 1-foot ground sample distance at 200-scale horizontal accuracy.

IV. Software Process Overview - General

- a. Pixxures in-house developed software process works through visual generation of “from/to” Links and adjusts locally on a nearest neighbor principle
- f. Enables data to be constrained as required to ground control, CoGo and survey data, section lines, boundary delineation, etc.
- g. Import and display “golden” vector layer superimposed over raster ortho-imagery
- h. Operator creates “Links” (from and to points) based on Photo identifiable hard features, apparent occupation, known distances and widths



From/to Links shown in red.
Lengths in excess of 300'

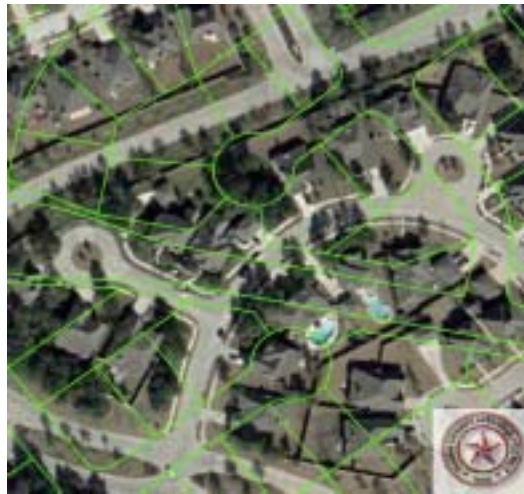
- i. Vector Layer is adjusted on the fly with each added, removed or edited link providing immediate feedback to the operator
- f. Enables large shifts of inaccurate data adjacent to accurate data (CoGo/Survey) requiring small shifts without affecting data integrity



Small shift 5-7 feet - before



Small shift - after



Large shift 300 feet plus- before



Large shift - after

- k. Links can be copied to ensure consistent shifts
- l. Entire “blocks” of data moved consistently at once
- m. Input data integrity is maintained – coincident data layers (nodes/shapes) remain in tact (Topology and polygon shape maintained.)
- n. Shift parameters are established on “golden layer” then applied to all “other” coincident layers to guarantee data cohesiveness/integrity
- o. Schedule and cost not dependent on number of associated coincident data layers (runs in batch in less than 10-minutes)

Jefferson County Specifics

- a. Pre-generate a set of links for each vertex in the PLS ¼ section lines to establish initial constraints.
- b. Node replication between coincident layers to ensure data integrity after adjustment
- c. Verify polygon count consistent against input count.
- d. Verify polygon area change within accepted tolerance
- e. Visual inspection per pilot result

V. Personal requirements

- a. Team leader (client side) needs strong background in cadastral data structure
- b. Well organized and full access to input data and supporting information
- c. Knowledge and history of data layers helpful

- d. Knowledge of pedigree of control helpful
- e. Resources to perform QC/Acceptance function is necessary to facilitate quick turn-around
- f. Clear understanding of the program goals, how it is to be assessed and the ability to convey that message due to subjective nature of the final data.

VI. Accuracy

Accuracy is more of a statement of objectives rather than a statistical process of measurement/assessment. Output accuracy is determined based upon the quality of the input data layers and the accuracy of the supporting control materials (orthophotography and other). Output accuracy cannot exceed the accuracy of the controls.

Sample verbiage from Jefferson County contract:

“Accuracy & Acceptance Criteria Statement

It is agreed by both parties that it is not possible to specify an “absolute” spatial accuracy specification in relation to this project, rather the adjusted data sets must be consistent visually with the 2002 image data provided as control, maintain a relative conformity to the original shape of the input data sets and be synchronous with respect to the adopted spatial datum. It is mutually agreed that the relative fit of the data themes in relation to the imagery established in the pilot project area (Township 41) will serve as the standard from which accuracy for the remainder of the county will be measured. In addition, the adjusted data must pass Jefferson Counties “Quality Control Matrices” prior to being accepted.”

VII. Other Applications (Average completion times)

Turn-around time is affected by many issues including the quality, consistency and knowledge of the input data. Client expectations with regard to fit/accuracy. Gathering, prepping and formatting of inputs if required. Some examples of turn-around on completed projects or expected schedule on other projects currently in-progress from Pixxures:

- a. Electric Utility – Parcel, facilities, control and annotation completed in 1-month



- b. Appraisal District – 1.2 MM parcels, 9-other layers and supporting annotation completed in 6-months
- c. Jefferson County – on track for estimated 4-month completion
- d. City – 6000 parcels, plan and annotation completed in three weeks
- e. Water Utility – 150-square miles (pilot in progress. Estimated at 30-day turn-around for entire area)
- f. Gas Pipeline – 11,000 linear miles (pilot in progress estimated at 5-month turn-around for entire area)

VIII. Conclusion

Bottom line, the technology works. As of this writing we have received over 70% of the data back and the results are excellent. The Assessor's office is delighted with product. Before and after products can be seen in figures 3 and 4. The rectified data will enable us to complete futures edits more quickly and accurately. We can now send data out to developers and have them use our base, drastically lowering our update costs. The truly synchronized data will now allow us to make spatial queries that result in meaningful answers. Simple questions like what is the zoning on that parcel and what is the setback on that structure can now be answered with high confidence.

The return on investment when compared to any other technology is huge. If we had done the rectification or if we had contracted out manual rectification it would have costs at least 1-2 million dollars and taken several years. Our return on investment is nearly 10 to 1 and the work will be completed in months instead of years.



Figure 3. Parcels before rectification on 1996 aerial imagery



Figure 4. Parcel after rectification in blue, parcels before rectification in red on 2002 aerial imagery. Note: The shift correction is in many directions relative to the image.

This technology represents a major breakthrough in one of most common problems facing any organization dealing with GIS and cadastral land records. Legally correct and spatially correct now mean virtually the same thing. Our spatial data is now synchronized and established on a high quality image base. We have literally saved our investment in GIS.

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