Accuracy Assessment of Map Coordinate Retrieval

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ABSTRACT: United States Geological Survey (USGS) 7.5-minute series topographic maps are widely used as reference maps for natural resource planning and management, particularly at the local and regional levels. This study assesses the accuracy of point coordinate retrieval from a stable-based USGS 7.5-minute series map using commercially available software and hardware. These coordinates were used as input data for creating a base map for a vector-based county geographic information system (GIS). Eight points, three horizontal control points and five road intersections, with verifiable locations on the ground were used to evaluate the accuracy of the retrieval procedure. A completely randomized block model was defined to evaluate errors due to operator, map position on the digitizing tablet, and points on the map. A second completely randomized model was used to verify the effect of points. The recovered coordinates of the three horizontal control points deviated from their survey position between 7 and 12 feet. Points strongly influenced by map feature exaggeration had deviations between 16 and 25 feet. Despite these deviations, the mean values (Euclidean distances) obtained for all points were well below the tolerance for this map scale (40 feet). These results show that the accuracy of point coordinate retrieval from stable-based USGS 7.5-minutes series maps, obtained with the procedure described here, is acceptable for the objectives and precision requirements for the base map of this rural GIS, in Miami county, Indiana, where collateral evidence is reliable.

INTRODUCTION

THE PRIMARY SOURCES OF DATA for a geographic information system (GIS) are maps which can be converted from analog to digital format and used in a variety of applications in natural resource management (Walsh, 1985; Niemann *et al.*, 1987; Ventura *et al.*, 1988). Data derived from different sources and in different formats have exhibited many type of errors. Further integration and manipulation of the data within a GIS can yield products of questionable accuracy (Vitek *et al.*, 1984).

Walsh *et al.* (1987) and Vitek *et al.* (1984) have discussed the occurrence of inherent and operational errors in a GIS. Inherent errors are those present in source documents, while operational errors are produced through data capture and manipulation procedures. The accuracy GIS products depends upon the requirements of the user, the characteristics of the source document, and the instruments used to create that document (Marble and Peuquet, 1983).

Positional accuracy of spatial features in a GIS is critically important to many users. A geodetic reference framework, which is the spatial foundation of any GIS, must provide an accurate and efficient means of positioning data and allow compatibility for the resulting products. The spatial requirements of such a reference framework will be defined by the users' applications (National Research Council, 1983; Epstein and Duchesneau, 1984). A base map is a graphic representation at a specified scale of selected fundamental map information, used as a framework upon which additional data may be compiled (Slama, 1980).

Because of their availability, completeness, cartographic detail, and low cost, United States Geological Survey (USGS) 7.5-minute series topographic maps (Quad maps) are widely used as reference maps for natural resource planning and management, particularly at the local and regional levels. Digital Line Graphs (DLGs), derived from USGS Quad maps, have been used in many GIS applications. Wolf and Slonecker (1989) derived large-scale DLGs (scale 1:12,000) from aerial photography and established control points from selected photo-identifiable coordinates of 1:24,000-scale topographic maps for site-specific studies on landfill contamination. Ventura *et al.* (1986) evaluated the quality of digital cartographic data used in the Dane County Land Records Project. They found DLGs to be accurate for GIS applications that require coarse accuracy (e.g., 30 m.), such as natural resource inventories. However, the scale of Quad maps may be inadequate if more detail is necessary, i.e., site-specific work such as location of utility lines, or urban applications. Croswell (1987) provides a clarification to the problem of absolute versus relative accuracy as associated with property boundaries which relates back to the specific need of the user. The needs of a rural area are very different from those of an urban or suburban area in that more precision is required in the latter areas.

The Laboratory for Applications of Remote Sensing (LARS) at Purdue University is conducting a pilot project in Miami county, Indiana, with the goal of combining remotely sensed and cartographic data in a GIS environment to address rural needs. The project is geared toward information needs for land appraisal, soil erosion, and soil management. Information to be incorporated in this vector-based GIS/land information system (LIS) includes rural land property, soils, land cover/land use, and related attributes (Johannsen *et al.*, 1990).

Control points tied to a geodetic network with appropriate density as to precisely identify rural property were not available to generate a reliable base map. Therefore, planimetric maps were used to create the spatial reference framework to which all other layers in this GIS/LIS were tied. This method has been deemed appropriate for creating GISs for rural environments, i.e., when large-scale analysis are not required (Kjerne and Dueker, 1984; Dueker *et al.*, 1985).

The objective of this study was to evaluate the accuracy of point coordinate retrieval from a stable-based USGS Quad map using commercially available software and hardware. These coordinates were then used as input data to create a base map for vector-based county GIS/LIS. Other layers of information were registered to this base map.

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MATERIALS AND METHODS

Cartographic Base and Accuracy Standards

The USGS Quad maps, scale 1:24,000, were chosen as the cartographic reference layer for the Miami County GIS/LIS. These maps are especially useful for planning in rural areas (Thompson, 1988; Ventura *et al.*, 1986; Koch and Johnson, 1989) and they provide complete coverage of the study area. Miami County is well developed, with roads and fences, which adds to the reliability of Quad maps as a source of cartographic reference.

The Public Land Survey System (National Research Council, 1982) was selected as the geometric framework to locate rural parcel boundaries for the ownership layer. Coordinate locations of all features were expressed in terms of the Indiana State Plane Coordinate System (ISPCS; Curtis, 1974) because of greater familiarity at the local level. This system was recommended for local multipurpose cadastres. State Plane Coordinates can be transformed into other coordinate systems, thereby permitting data correlation at regional, state, and national levels (National Research Council, 1983).

A 10,000-foot grid based on the ISPCS (1927 North American Datum) is printed on the USGS 7.5-minute maps. The NAD 27 has been superseded by the North American Datum of 1983 (NAD 83) which corrects for defects and inconsistencies within NAD 27. In the future all geodetic and land survey information can be expected to conform to NAD 83. The corrections due to NAD 83 will not cause any corrections for Indiana because the average shift is less than 10 metres while for areas like California the shift is as large as 100 metres. Persons using map measurements like those described in this paper will need to be aware of these differences when attempting to use our procedures (Moffitt and Bouchard, 1987). The U.S. National Map Accuracy Standards establish that, for maps with publication scales of 1:20,000 or smaller, not more than 10 percent of well-defined points tested shall be in error by more than 1/50 inch (40 feet on the ground) in a horizontal plane. Well-defined points are visible or recoverable on the ground (Thompson, 1988). In statistical terms this accuracy can be evaluated using the root mean square error (RMSE). For the horizontal tolerance of 40 feet, in a 1:24,000 scale map, the equivalent allowable RMSE is 24 feet (Thompson, 1988).

There are certain kinds of error in mapmaking that are unavoidable. Items such as names and symbols of features like roads or lakes are subject to factual error. There are also errors resulting from selection, generalization, and displacement when mapping complex features at reduced scales. Some items such as buildings may be slightly displaced so that a prominent features such as a roads can be shown in actual location (Croswell, 1987).

Hardware and Software

The Miami County GIS/LIS was developed on a microcomputer-based ARC/INFO[1] system. Stable-based maps were digitized using a GTCO[2] Digipad 2436A digitizing tablet. The tablet was configured to encode coordinates in ASCII format with an accuracy of ± 0.010 inch.

Map Setup Procedure

Before point coordinates are retrieved or maps are digitized, it is necessary to register the map by digitizing a minimum of four point locations on the map. Normally these points (tics) correspond to the corners of the map, and their coordinates are used to orient the map on the digitizer by establishing a transformation between the map and the digitizer. In ARC/INFO, a measure of the accuracy of tic registration is given by the RMS error, which is calculated through a six-parameter affine transformation.

Coordinates for 16 tics (which corresponded to intersections of latitude and longitude) were read directly from the Quad map and mathematically transformed from latitude/longitude to State Plane Coordinates for entry. The RMS error for this registration was 0.009.

For all practical purposes, an RMS error between 0 and 0.003 is suggested as acceptable when four tics are used for registration (ESRI, 1989). If three points were used for registering a map, a six-parameter affine transformation would render a unique solution because there would be no redundancy for error checking; in this case the RMS would be equal to zero. Four points (tics) provide a small amount of redundancy; therefore, there are residuals available at every point, and some statistical evaluation of the error can be done. As more points are added to the registration procedure, the estimations of the errors are statistically more valid. In this registration, we used tics evenly distributed over the Quad map to minimize the distortion that is imposed on points that are away from the tics used to define the parameters through the fitting (Sprinsky, 1985). The RMS error we obtained in this registration (0.009) is statistically valid and acceptable for the accuracy required in this project.

Location of Control Points

Eight points were selected to evaluate the precision of coordinate retrieval. These points corresponded to verifiable locations on the ground; all were included in the Roann Quadrangle, Indiana. Points HCS1, HCS2, and HCS3 are the National Geodetic Survey horizontal control points ROANN (N° 1039), EEL (N° 1012), and LUKENS (N° 1301), respectively (Table 1). ROANN and LUKENS are second-order triangulation stations with a third-order azimuth marks; EEL is a first-order triangulation station with a third-order azimuth mark. Descriptions of these three stations can be found in U.S. Department of Commerce (1959).

Points RI1 through RI5 are the road intersections around Section 9, T28N, R5E (Figure 1). The State Plane Coordinates of these intersections were provided by the Miami County Surveyor's Office. In order to calculate the State Plane Coordinates

Table 1. State Plane Coordiantes for Points Used in this Study: State Plane Coordinates (1–9), Road Intersections (RI1–5), and Horizontal Control Stations (HCS1–3).

Point	State Plane Coordinates		Coordinates obtained from
	x	*y*	
1	410000.00	1250000.00	Map
2	420000.00	1250000.00	Map
3	430000.00	1250000.00	Map
4	410000.00	1240000.00	Map
5	420000.00	1240000.00	Map
6	430000.00	1240000.00	Map
7	410000.00	1230000.00	Map
8	420000.00	1230000.00	Map
9	430000.00	1230000.00	Map
RI1	412769.67	1237023.07	Field Survey
RI2	418131.16	1237051.09	Field Survey
RI3	418200.55	1231912.28	Field Survey
RI4	412856.65	1231760.36	Field Survey
RI5	412816.69	1234357.66	Field Survey
HCS1	438122.55	1263126.11	NGS-USDOC*
HCS2	414232.06	1243246.89	NGS-USDOC*
HCS3	438525.52	1242675.74	NGS-USDOC*

*Published by the National Geodetic Survey-U.S. Department of Commerce (1959).

[1]ARC/INFO is a trademark of Environmental Systems Research Institute, Inc. (ESRI), Redlands, California.

[2]GTCO Corporation, 1055 First Street, Rockville, MD 20850.

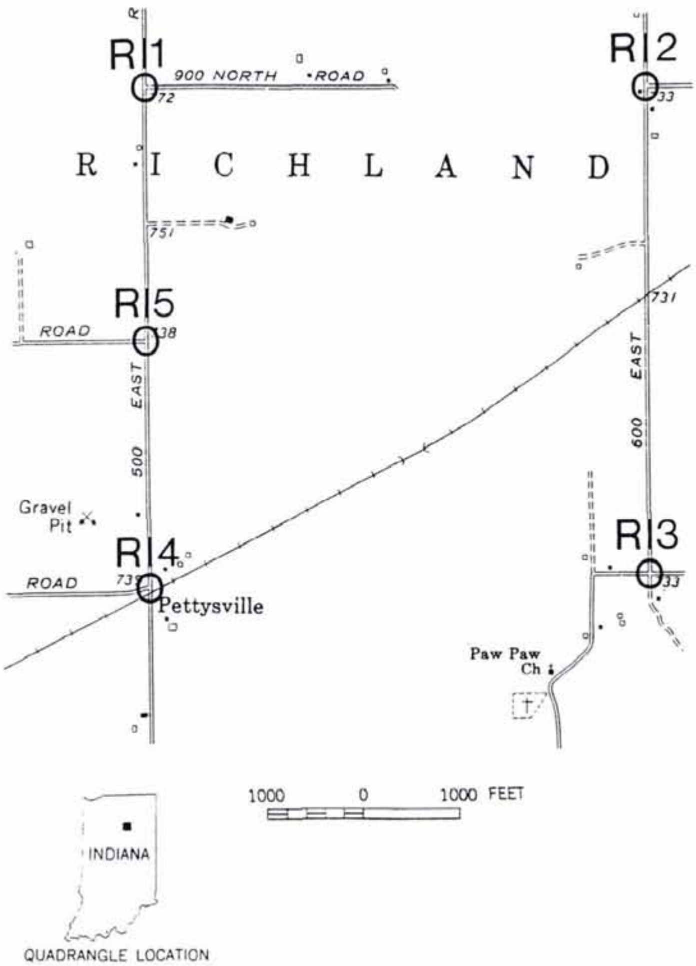

FIG. 1. Portion of the USGS 7.5-minute series ROANN Quadrangle, Indiana, showing the location of road intersections (RI1 to RI5) around Section 9, T28N, R5E, used in the statistical analysis.

of intersection corners, the Surveyor's Office gathered information about the location of the stones used to indicate the center of each intersection, and then marked the approximate location of each corner stone on aerial photographs. This information was used to locate the stones in the field. Corner stones were excavated, and an aluminum monument was placed over each stone to raise its location to the surface. The corner stones were then available for survey. On intersections which did not contain stones, the center of the intersection was determined to be the centerline of the existing pavement.

The next step was to survey a traverse from the ROANN triangulation station, which was the nearest point with the known State Plane Coordinates. A six-second theodolite was used to measure the angles in the traverse with each angle being measured three times by an Electronic Distance Measuring (EDM) device. A closed-loop traverse was used which included each of the section corners starting from the ROANN station in a south west direction and proceeding around Section 9 counter-clockwise. The measured angles were adjusted and corrected to grid azimuth. The field distances were corrected to grid distances which included the reduction of the distances from ground level to mean sea level distance, and then to a grid length distance on the plane of the State Plane projection system. The length of the traverse was 31,409.29 feet, and the misclosure was 0.64 feet. The traverse was adjusted to distribute the 0.64 feet among all points within the traverse (accuracy: 1 in 48,800). Finally, the traverse was adjusted, and the x and y coordinates for road intersection were obtained (Table 1).

DESIGN OF EXPERIMENTS

Because the main interest of this work was to compare the difference between the location of a point on the ground (true location) and its position on the map (retrieved location), the statistical analysis in both experiments was performed for the Euclidean distance between the two points rather than for variations in the x and y directions. Two experiments were designed to assess the statistical accuracy of the coordinate retrieval process.

The first experiment was developed to evaluate errors caused by operator, map position on the digitizing tablet, and points on the map. A completely randomized block model was defined with two operators, two map positions, nine points, and three replications per point. The Analysis of Variance (ANOVA) model is shown in Equation 1 (Anderson and McLean, 1974).

$$y_{ijk} = \mu + O_i + P_j + \delta_{(ij)} + R_k + \varepsilon_{(ijk)} \qquad (1)$$

where

- y_{ijk} = the differential distance as measured from the map, for the k^{th} point, by the i^{th} operator, and the j^{th} position
- μ = overall mean
- O_i = effect of the operator
- P_j = effect of map position
- $\delta_{(ij)}$ = restriction error caused by nine points measured by the i^{th} operator, at the j^{th} position
- R_k = effect of point location
- $\varepsilon_{(ijk)}$ = random error

For this model, two experienced operators retrieved the coordinates of nine selected points. The points corresponded to intersections of the State Plane Coordinate System as indicated on the USGS 7.5-minute series topographic maps. The x and y coordinate values for each intersection were obtained directly from the map (Table 1). Points 1, 3, 7, and 9 were used as tics for map setup; points 2, 4, 5, 6, and 8 were used for the analysis (Figure 1).

We developed a second ANOVA model to evaluate the precision of the coordinate retrieval procedure, after we analyzed the results of the first model. This second model was defined with one operator, a single map position, six points, and three replications per point (Equation 2; Anderson and McLean, 1974).

$$y_i = \mu + R_j + \varepsilon_{(i)} \qquad (2)$$

where

- y_i = the differential distance as measured from the map for the i^{th} point
- μ = overall mean
- R_j = effect of point location
- $\varepsilon_{(i)}$ = random error

In this model the tics were 16 intersections of latitude and longitude in the Roann Quad. The eight points used to assess precision were horizontal control stations and road intersection points; all with known locations on the ground. See section on Location of Control Points (Figure 1, points: HCS1 to HCS3, RI1 to RI5; Table 1).

A Student-Newman-Keuls test at the $\alpha = 0.10$ level was used to evaluate possible pairs of means (Anderson and McLean, 1974). The Shapiro-Wilk test applied to check for normality of the data (Shapiro and Wilk, 1965).

RESULTS AND DISCUSSION

The value of the Shapiro-Wilk test for normality is given by *W:Normal*, where $0 < W \leq 1$. Values of W closer to 1 mean that the data are from a normal distribution. Values of W for Δx and Δy in Table 2 indicate that the data follow a normal distribution. The Stem-Leaf and Box plots in Figure 2 show the distribution of the sample values and, therefore, provide an indication of their dispersion and normality.

TABLE 2. RESULTS OF THE SHAPIRO-WILK TEST FOR NORMALITY OF DATA. DIFFERENCES BETWEEN MEASURED VALUES (DIGITIZER) AND TRUE VALUES (MAP OR FIELD DATA) FOR ALL DATA POINTS, IN THE X (ΔX) AND Y (ΔY) DIRECTIONS.

Variable	Δx	Δy
Number of samples	132	132
Mean	3.2860	3.8212
Standard Deviation	13.0857	9.0696
W:Normal	0.8499	0.9195

A Variable= Δx

```
Stem Leaf Plot                      #     Boxplot
  4 6                               1        *
  4 023                             3        0
  3 6                               1        0
  3 001233                          6        0
  2 799                             3        0
  2 023                             3        |
  1                                          |
  1 011124                          6        |
  0 555556666678888999999          21     +-----+
  0 000000111111111111222334444    27     *--+--*
 -0 44433333322222222111111110     26     |     |
 -0 888877666666655555             18     +-----+
 -1 44433332221110000              17        |
    ----+----+----+----+----+--
 Multiply Stem.Leaf by 10**+1
```

B Variable= Δy

```
Stem Leaf Plot                      #     Boxplot
 26 07                              2        0
 24 00770                           5        0
 22 0                               1        |
 20 00                              2        |
 18 096                             3        |
 16 09906                           5        |
 14 00000                           5        |
 12 006                             3        |
 10 000                             3        |
  8 00330                           5     +-----+
  6 0003000999                     10     |     |
  4 000000000000                   12     |     |
  2 000000000000                   12     *--+--*
  0 000000000003                   12     |     |
 -0 001                             3     |     |
 -2 00009997110000000000000        23     +-----+
 -4 0000000000000                  13        |
 -6 700000                          6        |
 -8 00                              2        |
-10 0000                            4        |
-12                                          |
-14 0                               1        |
    ----+----+----+----+---
```

FIG. 2. Stem-Leaf plots and Box plots for Δx (A) and Δy (B). *---* indicates the median; + indicates the mean; the upper and lower ends of the box (+---+) indicate the 25th and 75th percentiles of the distribution.

The Stem-Leaf plot in Figure 2a shows that some values of Δx are shifted towards the upper range of the distribution (from 20 to 40 feet). This shift causes a slight skewness to the right, and results in a larger standard deviation than for Δy (Table 2). The Box plot shows that the mean and the median fall on the same value. The median is located close to the 25th percentile of the distribution, indicating a slight skewness of the values (Figure 2a).

The Stem-Leaf and Box plots for Δy (Figure 2b) show results similar to Δx, but Δy values follow a more normal distribution: values are located around zero, and there are very few outliers. The mean and the median also fall on the same value, and the median is located in the middle of the box. Despite some outliers for Δx, all data (Δx and Δy) follow a normal distribution.

The first ANOVA model (Equation 1; Table 3) shows that operator, map position, points, and the interaction of map position by points are highly significant. In addition, the values for point deviation are high (more than 22 feet for points 2 and 5). The results obtained for the first ANOVA model indicated that only one operator in a single map position should perform the coordinate retrieval. The high values obtained for the intersection points 2, 4, 5, 6, and 8 could be due to the way these points were defined on the map. State Plane Coordinate tics are marked at the edges of the map. Therefore, to mark an intersection of coordinates within the map it is necessary to draw a line connecting the tic marks. This is one source of uncertainty. The thickness of the line to mark the intersections also could have contributed to the error of these measurements.

In view of the results obtained for the first model, the second

TABLE 3. RESULTS OF THE ANOVA MODEL #1.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	27	7856.3842	290.9772	19.35	0.0001
Error	32	481.1593	15.0372		
Corrected Total	59	8337.5435			
Source	**DF**	**Anova SS**	**Mean Square**	**F Value**	**Pr > F**
OPERATOR		115.0143	115.0143	13.73	0.0060**
POSITION	1	1079.7716	1079.7716	128.93	0.0001**
OPERA*POS	1	22.5645	2.5645	2.69	0.1393
REPET (OPERA*POS)	8	66.9971	8.3746	0.56	0.8045
POINT	4	1178.6910	294.6727	19.60	0.0001**
OPERA*POINT	4	71.2038	17.8009	1.18	0.3366
POS*POINT	4	5200.3960	1300.0990	86.46	0.0001**
OPERA*POS*POINT	4	121.7459	30.4365	2.02	0.1146

SNK Grouping*	Mean (in feet)•	N	VARIABLE
			OPERATOR
A	19.2	30	2nd
B	16.5	30	1st
			POSITION
A	22.1	30	2nd
B	13.6	30	1st
			POINT
A	22.9	12	2
A			
A	22.6	12	5
B	16.6	12	8
B			
B	16.2	12	4
C	11.0	12	6

*Means with the same letter are not significantly different.
**Highly significant.
•Results reported to one decimal point.

ANOVA model (Equation 2) took into account only points with known location on the ground. HCS1, HCS2, and HCS3 are points surveyed with great precision and accuracy because subsequent surveys will depend on these control points for accurate positioning (Thompson, 1988). Control points are printed on maps following very accurate photogrammetric and cartographic procedures.

The results of the second ANOVA model (Table 4) indicate that control points HCS2 and HCS3 had the lowest deviation from true location, between 7 and 10 feet. The small deviation values obtained for these two points were originated in hardware limitations and operational errors. Control point HCS1 had a higher deviation (12.2 feet). According to the USGS-National Mapping Division, the deviation of HCS1 is due to an anomaly of the map: the plotting of this control point appears to be inconsistent with published coordinate data (W. Chapman, personal communication, 1990). Points HCS1 and HCS3 were grouped together; the difference between these two points was not statistically significant. On the other hand, point HCS2 was included in a different group, and the difference between HCS2 and HCS1 and HCS3 was statistically significant (Table 4).

The road intersection points presented two different results. The road intersection located in the north east corner of Section 9 (RI2, Figure 1) had the smallest deviation of all intersection points; thus, this point was included in the same group with points HCS1 and HCS3, according to the statistical results. The other four road intersection points (RI1, RI3, RI4, and RI5, Figure 1) had deviations between 16 and 25 feet. These points were combined in three groups, and the difference in deviations among the three groups were statistically significant (Table 4).

The center and orientation of a symbol normally correspond with the center and orientation of the feature represented; but, when linear features which run parallel to one another (roads, railroads, streams) are represented with the proper symbols, it may be necessary to exaggerate the area covered by those features. On a 1:24,000-scale map the minimum symbol width represents 40 feet on the ground (Thompson, 1988).

Roads are represented as parallel lines on maps, and most roads are too narrow for clear delineation at 1:24,000 scale; therefore, there is always a doubt when trying to find the precise location of these points on a map. The larger deviations obtained for road intersections RI1, RI3, RI4, and RI5 were then caused by the uncertainty of identifying the true location of these intersections on the map, rather than any errors during field work (see section on Location of Control Points).

Table 4. Results of the ANOVA Model #2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	826.36643	118.0523	40.04	0.0001
Error	16	47.17508	2.9484		
Corrected Total	23	873.54151			

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
POINT	7	826.36643	118.0523	40.04	0.0001**

SNK Grouping*	Mean (in feet)♦	N	POINT
A	25.4	3	RI3
B	21.1	3	RI1
B			
B	19.4	3	RI4
C	15.8	3	RI5
D	12.2	3	HCS1
D			
D	11.1	3	RI2
D			
D	9.9	3	HCS3
E	7.2	3	HCS2

*Means with the same letter are not significantly different.
**Highly significant.
♦Results reported to one decimal point.

CONCLUSIONS

Point coordinate retrieval should be performed by the same operator using a standardized procedure to minimize sources of error. With small maps, the same position on the digitizing tablet should be maintained throughout the work. Errors should be quantified and reported so users will be aware of them. Then, the significance of the errors, their influence on map accuracy, and their effect on feature location in the maps will be known.

Coordinates of points accurately surveyed and precisely located on the map, such as horizontal control points, deviated least from true locations (less than 10 feet). The deviation obtained for HCS1 (LUKENS control station) is due to an anomaly of the map; therefore, this point should not be considered as representative of the accuracy that is possible to obtain from control stations. The largest deviations were, then, obtained from points strongly influenced by map feature exaggeration (between 11 and 25 feet). Despite these deviations, the mean values (Euclidean distances) obtained for all road intersection points and horizontal control points were well below the tolerance for this map scale.

These results show that the accuracy of point coordinate retrieval from stable-based USGS 7.5-minute series Quad maps, obtained with the procedure described here, is acceptable for the objectives and precision requirements for the base map of this rural GIS/LIS. Although the results presented here are suitable for Miami County, Indiana, where collateral evidence is reliable and clear to the county surveyor, we realize that this might not be case in other areas, where such collateral information can lead to important errors in the location of features. In all cases, the location of features, such as section corners, should be verified by a land surveyor with proper knowledge of the area.

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Young Authors' Competition 17th ISPRS Congress

The success of the ISPRS XVI Quadrennial Congress in Kyoto, Japan in 1988 inspired the Japan Society of Photogrammetry and Remote Sensing to donate 10,000 Swiss francs as a contribution to the activities of ISPRS.

The ISPRS Council, welcoming the creative Japan society donation, has determined that this money should be awarded in the form of travel subsidies to encourage young authors to participate in the 17th ISPRS Congress at Washington, DC, USA, 2-14 August 1992. Awards of 2,500 SFr each (about $1,750 US) are to be given to four individuals (not joint authors) whose submitted papers are judged the best. These individuals must be 35 years of age or younger on the 2nd of August 1992. The council will complete its judgments in time to offer the travel subsidies to the four winning young authors prior to the 17th Congress.

Young authors who wish to be considered for the awards should request and submit a completed Form for Abstracts to receive an ISPRS Congress Author's Kit. The Form for Abstracts must be submitted by 30 November 1991.

Submission date for the final version of the paper is 15 February 1992. At that time, an additional copy of the final paper, together with evidence of birth must be submitted to ISPRS President, Prof. Dr. Kennert Torlegard, who will coordinate the judging of the papers.

Results will be announced 15 May 1992, and authors will be informed immediately. The winners of the travel subsidies will be expected to present their papers at either a technical or poster session at the Congress.