Upgrading Real Property Boundary Information in a GIS

Raymond J. Hintz and Harlan J. Onsrud

Raymond Hintz is an assistant professor in the Department of Surveying Engineering at the University of Maine. His research interests include automated data collection, photogrammetry, and the reduction and analysis of surveying measurements.

Harlan Onsrud is an assistant professor in the Department of Surveying Engineering at the University of Maine and a research scientist with the National Center for Geographic Information and Analysis. His research interests include the diffusion of geographic information innovations, and legal and liability issues impacting digital data environments.

Abstract: *One difficult issue facing geographic information system (GIS) developers in the United States today is the current inability to create spatially accurate, legally supportive and operationally efficient land ownership databases. Solutions providing strong legal foundations for GIS are not simple. Often repeated attempts at digitizing inconclusive cadastral data and cross-referencing title information are stopgaps at best. Methods for supplying comprehensive and officially sanctioned cadastral data are currently being investigated.*

This paper describes technology for establishing a measurement-based management system at the local government level. The audience will gain an understanding of how sophisticated surveying computations, least squares analysis, statistical techniques, and blunder detection methods have now been packaged in an automated black box. Tools which were available previously to only highly specialized surveying experts are now potentially useable by surveying technicians. Through use of these powerful tools, maintenance over time is readily achievable for cadastral measurements in a GIS database.

Many current and potential users of automated geographic information systems are ultimately interested in use, control, or management of real estate or the resources associated with it. Thus, almost all current and future users of GIS eventually ask: *Who owns the land and what are the limits of that ownership?*

In practice, methods for providing a reliable link between legal ownership interests in land and the physical location of those interests are largely nonexistent in the United States. The availability of tax assessor maps has made them the convenient choice as the cadastral base for most local geographic information systems now being assembled in the United States. However, tax assessor maps were never intended to provide highly accurate, legally defensible descriptions of individual parcels in a jurisdiction. The danger in using conventional tax maps as the basis for the cadastral layer in an automated land information system is that data derived from or dependent upon this layer will give a false impression of high accuracy, and that derived data appearing on the computer screen could be sanctioned by the local government. Derived data are likely to be relied upon in situations where they should not be used and as a result cause damages.

Ownership rights in real property under the U.S. legal system are defined by the owner's deed and the chain of instruments that precede that deed. Therefore, it is desirable to utilize the boundary description in the cadastral layer, if possible.

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A problem arises in that many deed descriptions, although clear on their face, are unclear when attempts are made to precisely locate the described parcel on the physical earth. Land surveyors professionally interpret the evidence called for in individual conveyance instruments in carrying out property surveys. As a result, the best available evidence for precisely locating the deed-described bounds of a parcel typically consists of the measurements made by land surveyors (Dansby and Onsrud 1989).

Figure 1 provides a model for a useful multipurpose cadastral system. Surveying measurements tied to ownership parcels provide the crucial link between those land attributes determined primarily through physical observations and those attributes determined primarily through resort to legal system considerations and definitions.

Providing Strong Legal Foundations

Solutions in providing strong legal foundations for GIS are not simple. In developing an ideal land ownership database, several major needs become immediately evident.

- **The land ownership database must be spatially accurate**—down to the precision that surveying measurements allow. If a future user of the GIS wants to overlay the cadastral layer with a building layer which has been mapped photogrammetrically, the GIS should be able to indicate allowable setback distances to the property lines. In other words, if a firm tie to legal rights in land is desired, the spatial accuracy of the cadastral parcels should be as good or better than that required by any other layer.
- **The ideal cadastral database should be operationally efficient.** An example input system is shown in Figure 2. A secretary should be able to enter data into the system and a surveying technician should be able to operate it. The system should identify any blunders that the secretary might make, as well as identify blunders in measuring that land surveyors feeding data into the system might make. While various types of numerical blunders must be identified, it is also very important to identify various types of station labeling problems. Two examples of the latter include different points having the same name and a single point having more than one name.
- **The database should be legally supportive.** In other words, the land ownership database should be based upon the documents the legal profession will resort to in the event conflicts between adjoining parcels arise.

Objectives for an Automated Measurement Management System

In the authors' view, such a database is supportable most efficiently through an automated measurement management system. The ideal automated measurement management system should carry out a great deal of sophisticated measurement analysis. However, that sophistication should remain invisible to the typical user. The system should provide valid answers but ask very few questions of the user.

The ideal cadastral database contains measurements. There should be no derived data, adjusted data, or massaged data in the system. Only directly observed data should be contained in the database. The management system should handle all computations leaving little for the surveyor to do beyond identifying property corners on the ground and reporting measurements.

A well-designed measurement management system should identify any blunders in measuring or labeling that the surveyor may have made in the field. For instance, if a measurement is reported as 44.35 when it should have been 44.53, the system will indicate a probable blunder in that measurement.

Without human intervention, the system should automatically compute the coordinate values of all parcel corners in the system. The system should indicate graphically and numerically the reliability of each derived corner location.

The system should be established such that each time additional measurements are fed into the system, it must be verified that the new data are consistent with the existing data. If new measurements appear to be less accurate than previous measurements to the same monuments, warnings should be output to the operator. If old measurements in the system are found to be blunders or substantially less accurate than new measurements, similar indicators must clearly identify the situation to a user.

Land records are housed and administered primarily at the

FIGURE 1.
Model of a Multipurpose Cadastre

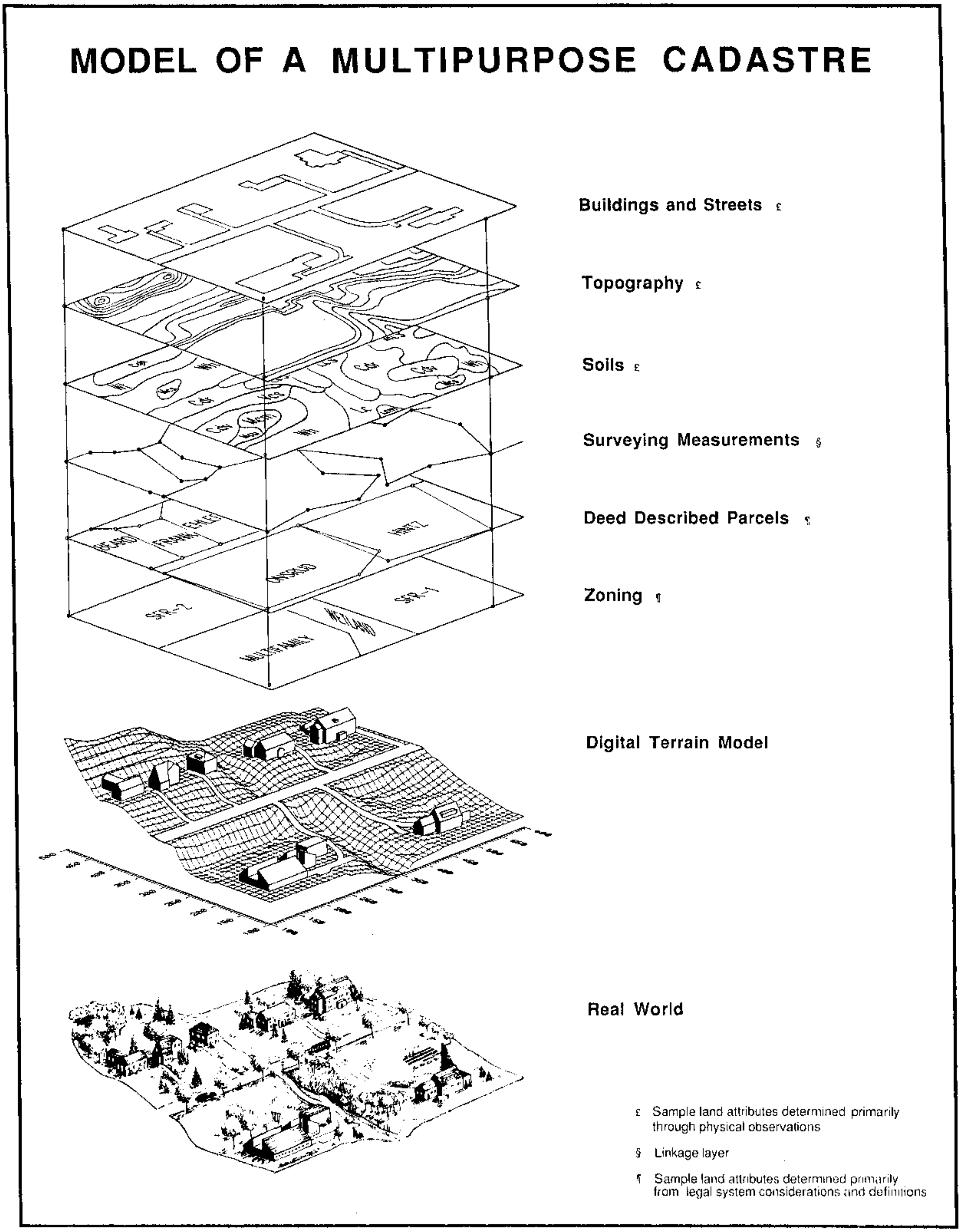
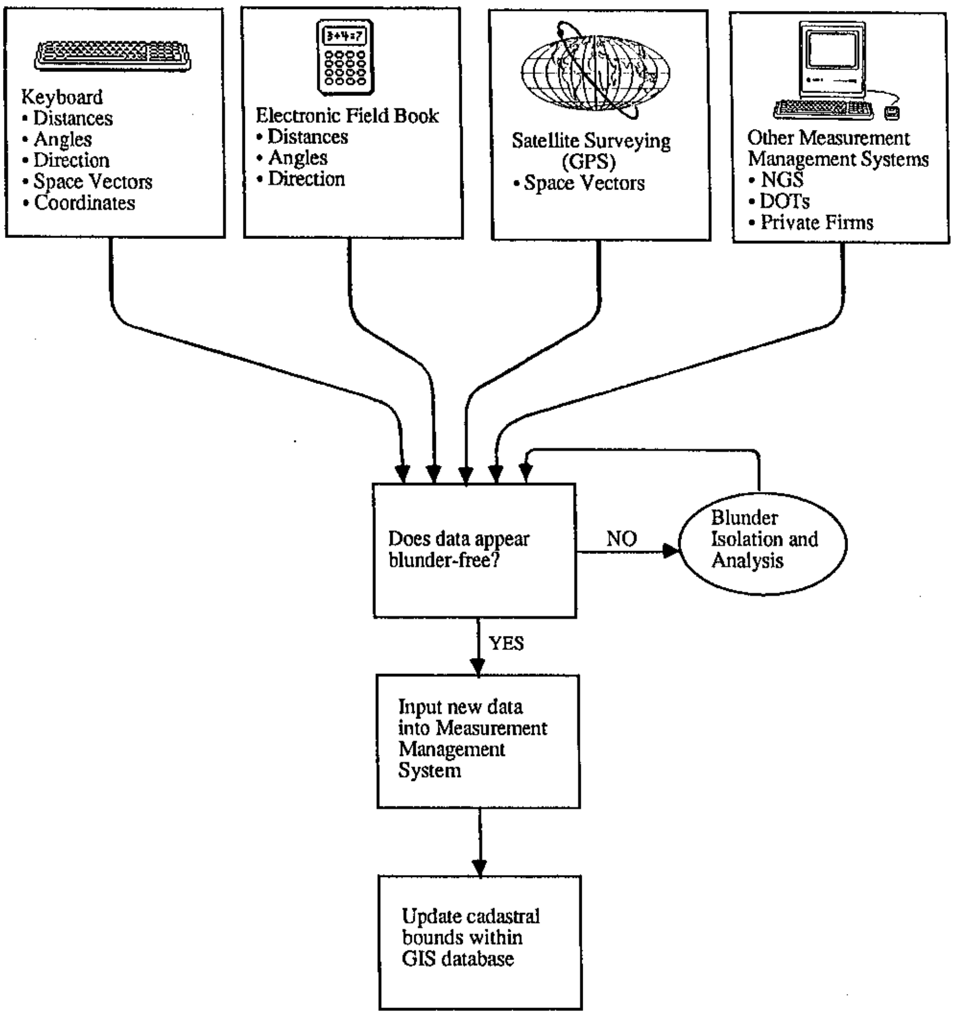


FIGURE 2.
Measurement Input



county or local government level in the United States. Therefore, the centralized automated measurement management system should be operated by the GIS cadastral layer manager at this facility. Private sector users would access information via modem. They should have the ability to add data for subsequent verification and input, and also retrieve data in a localized area of concern. The accessibility of the information is required for success of the measurement management system.

An Operational Automated Measurement Management System

A prototype system meeting many objectives just described has been developed (Hintz, *et al.* 1988). The system is currently being used and tested by the U.S. Bureau of Land Management and several private surveying firms. The system has also been used to establish cadastral survey control networks for the city of Altamonte Springs, Florida and Orange County, Florida. The system has recently been updated to input and analyze survey measurements collected on a hand-held PC equipped with data collector software. This collector can be interfaced to any commercially available total station. Use of the system in practice is explained through a series of simplified figures.

Presume that a measurement based cadastral layer in a GIS is to be established. The parcels illustrated in Figure 3 are the first four parcels which will be entered into the database. Presume for purposes of this initial example that the deeds of the adjoining owners describe the same corner monuments and that conflicts between the ownership lines do not exist.

Figure 4 shows the survey traverse network completed around each land parcel. The accompanying table shows how conventional terrestrial survey measurements were recorded. Unlike traditional traversing, notice there is no need to keep track of the order in which survey measurements were collected. In addition, the survey measurements could have been made by radial survey rather than by traverse. There is no difference in the data entry procedure for this type of data collection. A different file structure is used for vectors derived from use of the Global Positioning System (GPS).

FIGURE 3.
Deed Parcels

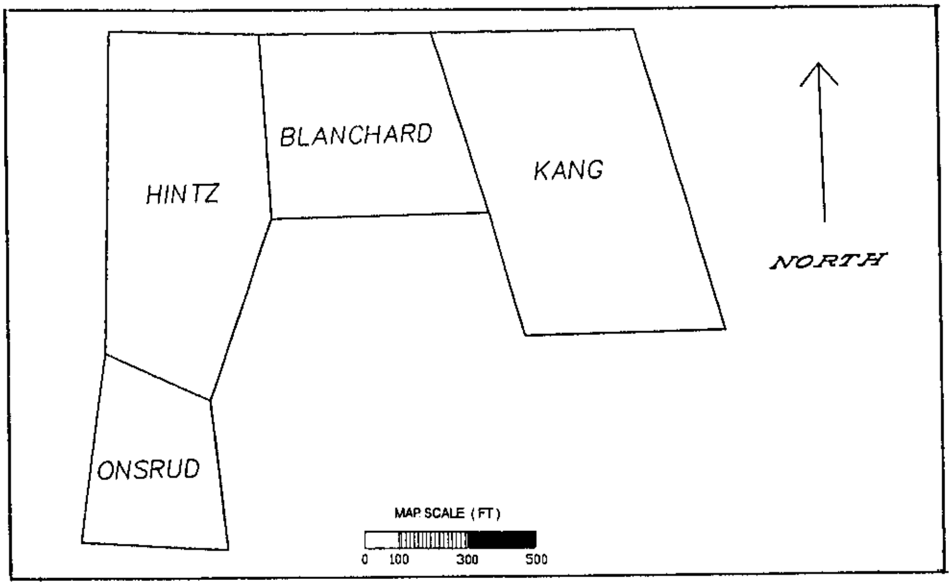
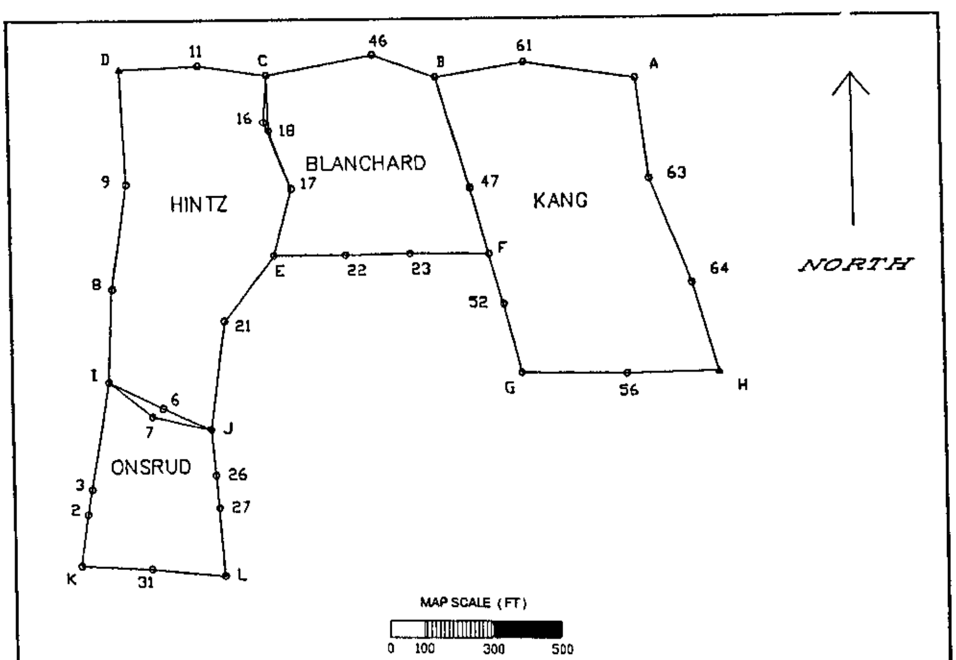


FIGURE 4.
Survey Traverse and Portion of Surveyor's Measurements



SURVEYORS MEASUREMENTS FOR A PORTION OF THE TRAVERSE

OCCUPIED STATION	SIGHTED STATION	DISTANCE	ANGLES BACKSIGHT	ANGLES OCCUPIED	ANGLES FORESIGHT	MEASUREMENT
B	47	347.130	61	B	47	83-15-44
42	F	203.400	B	47	F	181- 2- 3
F	52	155.310	47	F	52	179-36-41
52	G	212.960	F	52	G	181-47-46
G	56	310.650	52	G	56	104-30-10
56	H	276.430	G	56	H	178-10-53

After entering the data into the computer by keyboard entry, or by automatic file transfer from a data collector or vectors from GPS processed files, blunders in the data are automatically isolated in a user-friendly pre-least squares routine (Vonderohe and Hintz 1987). After any exposed blunders are corrected by the operator, automated initial coordinate generation occurs for added points in the system (Vonderohe and Hintz 1986). Then least squares analysis occurs. Blunders undetected in the pre-analysis stage may now be identified by several quality control procedures. Post-least squares processing completes the tasks of calculating coordinate standard errors, error ellipse information, residuals for all measurements, post-adjustment traverse misclosures (automatic and/or user-defined routes), adjusted bearings and distances for desired lines, coordinate lists and drawing files that are in a format readable by other software systems (Onsrud and Hintz 1989).

Figure 5 shows the error ellipses (one sigma) that may be automatically generated and drawn by the system. Error ellipses represent the magnitude of the uncertainty of coordinates in 2-D space, and can be automatically determined at a user-prescribed confidence level. Notice the map scale for the error ellipses is different from that of the traverse legs. For instance, the major axis length for the error ellipse at property corner L is approximately 0.075 feet whereas the distance from K to L is approximately 428 feet. In all examples, stations D and H had fixed (constrained) coordinate values from a previous survey. In a readjustment of a larger data set that contains the shown data, it may be desirable to constrain stations other than D and H (possibly geodetic control stations), but constraints on measurement data need to be handled on a case-by-case basis. Since measurement information is retained, the adjustment becomes a verification of data quality and not a determination of final coordinate values.

Presuming that the error ellipses are small enough for any immediate purposes intended, best estimates of the bearings and distances for all the parcel boundaries may be generated. If a survey plot is desired, additional labels, tables, and headers can be easily added in a CAD or GIS environment to which the measurement management information has been digitally imported. The resulting plat is illustrated in Figure 6. Thus, the system developed so far shows that it is possible with very little human intervention to generate a final plat with little more than angles, distances, and labels as input into an automated measurement management system.

In Figure 7, an additional land parcel has been added to the cadastral base (i.e., Cook) and another has been subdivided (i.e., Hintz into Hintz and Zhao). The additional survey measurements are added to the database and the resulting network hubs are illustrated in Figure 8.

The software described previously is run once again and error ellipses are generated as illustrated in Figure 9. Notice that because of the additional

FIGURE 5.
Error Ellipses

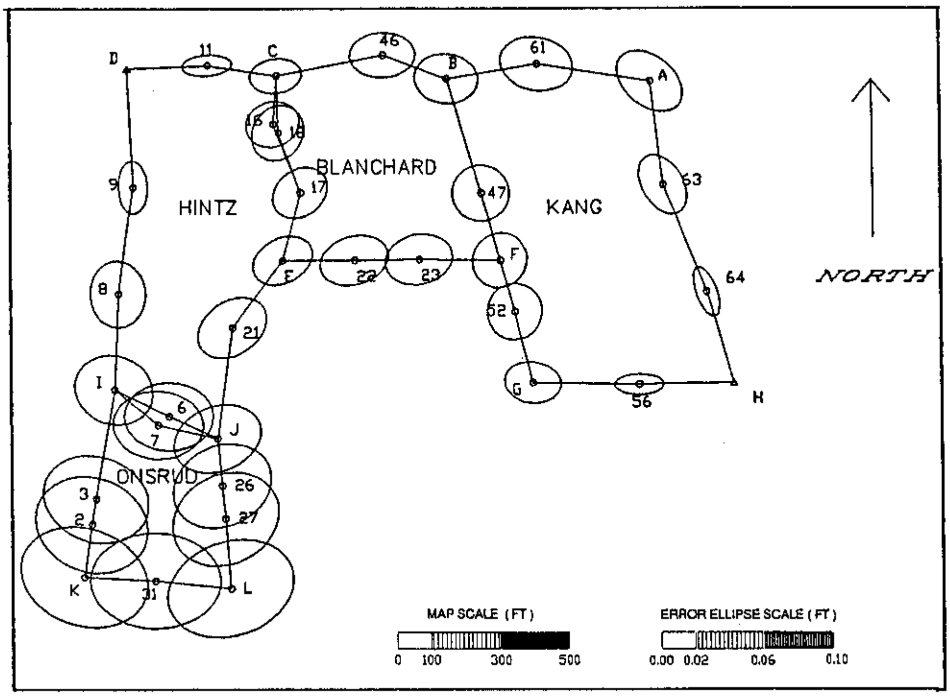


FIGURE 6.
Cadastral Plat

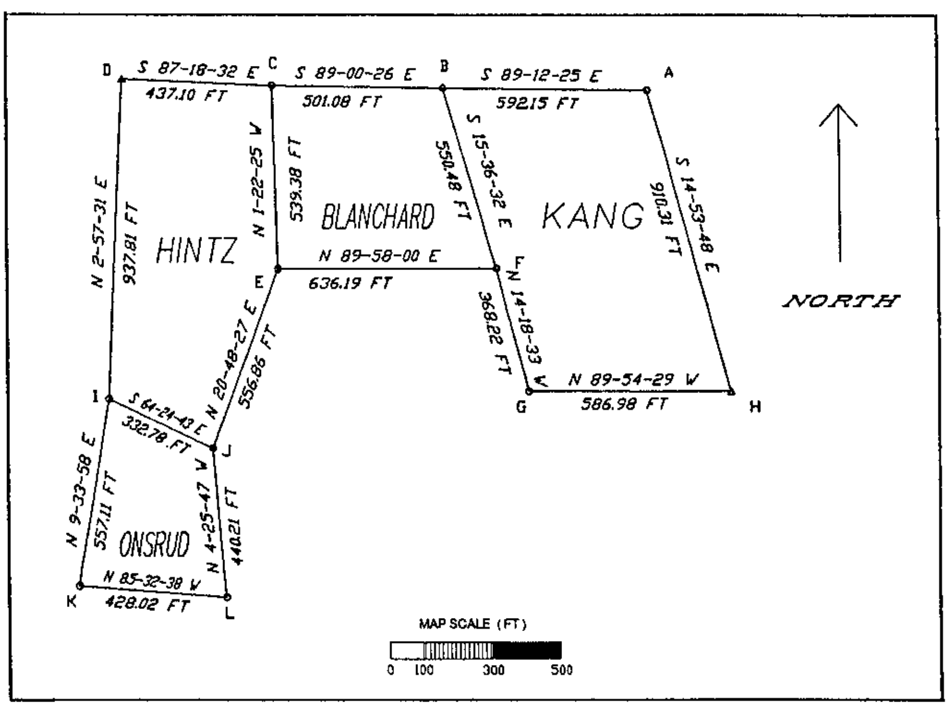


FIGURE 7.
Deed Parcels Updated

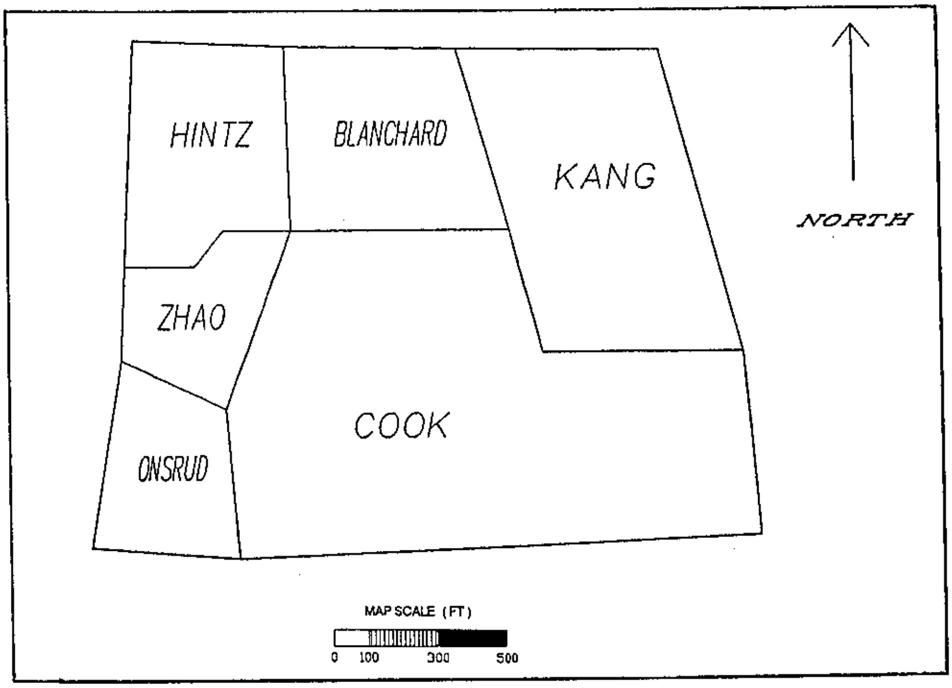
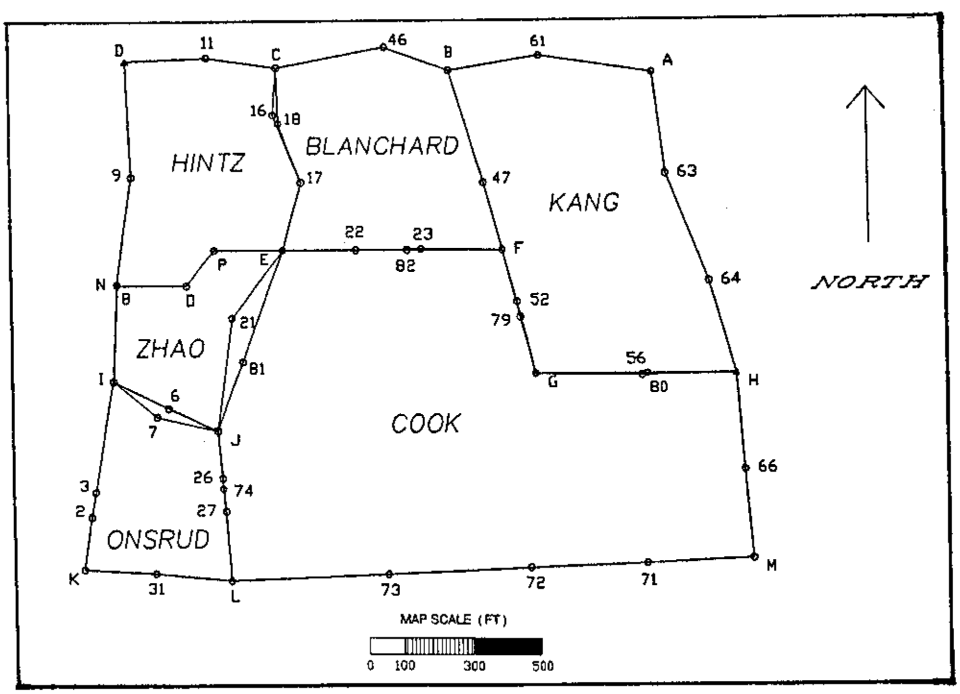


FIGURE 8.
Updated Survey Traverse



measurements the reliability of the derived position of point L has increased and the major axis of the error ellipse at that point has decreased to approximately 0.045 feet.

Once again, in Figure 10, the final plat is generated digitally. Notice that some distances and bearings have changed slightly from those in Figure 6. This is due to the added measurements and increased resultant reliability of the derived corner positions. Thus, the database upgrades itself over time. This upgrading of information solves many of the temporal problems in survey measurement maintenance. At some point in time, the positions of the property corners become known to an adequate degree of reliability for almost all land ownership purposes. At that point, it is no longer necessary to add further measurements to the database except perhaps as a check on those new observations. If a survey monument is destroyed and the position needs to be relocated, the information in the measurement management system is easily accessed to reliably relocate the original position.

If a well-planned labeling scheme is employed, it is possible to let numerous "islands" of survey networks grow in a community over time. Perhaps none of these islands will be tied to geodetic control initially. For instance, each island of parcels might assume an independent coordinate system. Over time, as measurements are added to the database which links islands together, larger islands are formed. Eventually islands are encountered that have been tied to geodetic control monuments or contain GPS observations. At that point, interconnected links can be automatically referenced to the absolute coordinate system.

It is important to recognize that the entire measurement management data set need only be completely readjusted fairly infrequently (Hintz, *et al.* 1988). This is crucial as readjustment of the entire data set could require the simultaneous solution of tens of thousands of equations for data in a metropolitan area. This would be very time consuming on a PC-based system. Local adjustment of data occurs frequently as data are added and need to be verified.

Further Developments

It is not suggested that massive remapping or resurveying programs should be promoted to secure validity of the information in the cadastral layer of a GIS. Such programs are generally unwarranted. When a real property conveyance takes place in the United States, survey measurements usually are made of that parcel. If a systematic means can be devised to capture the data already being collected, the cadastral database desired by many potential GIS users will become a reality.

Use of the described system to compile and maintain ownership line locations in a GIS does not suggest that property lines digitized from tax maps should be thrown out. That information is sufficient for many intended purposes. The current challenge for the surveying and GIS academic community is to develop a means of

FIGURE 9.
Updated Error Ellipses

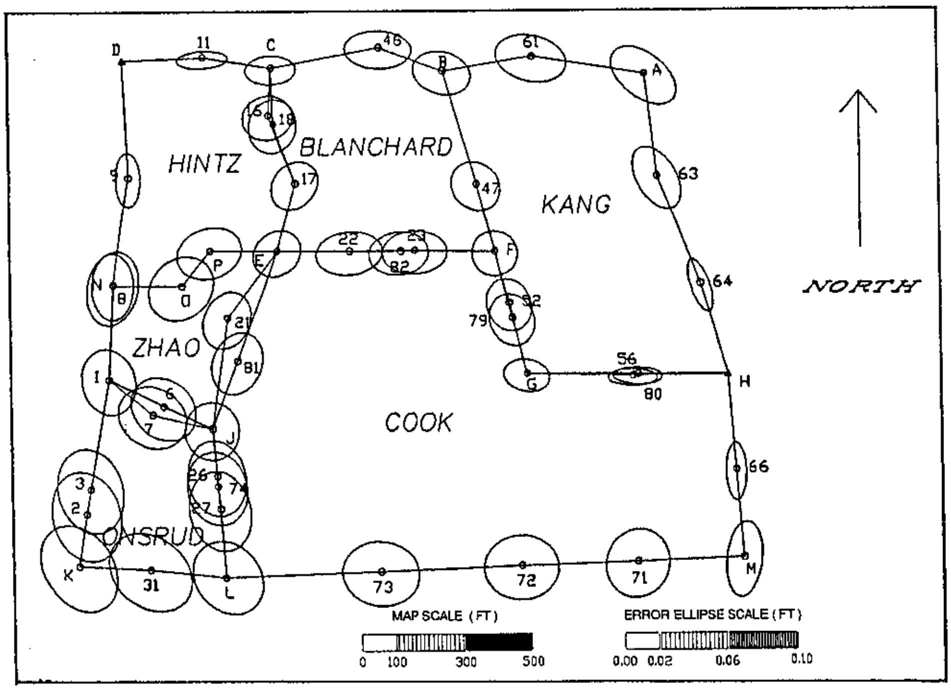
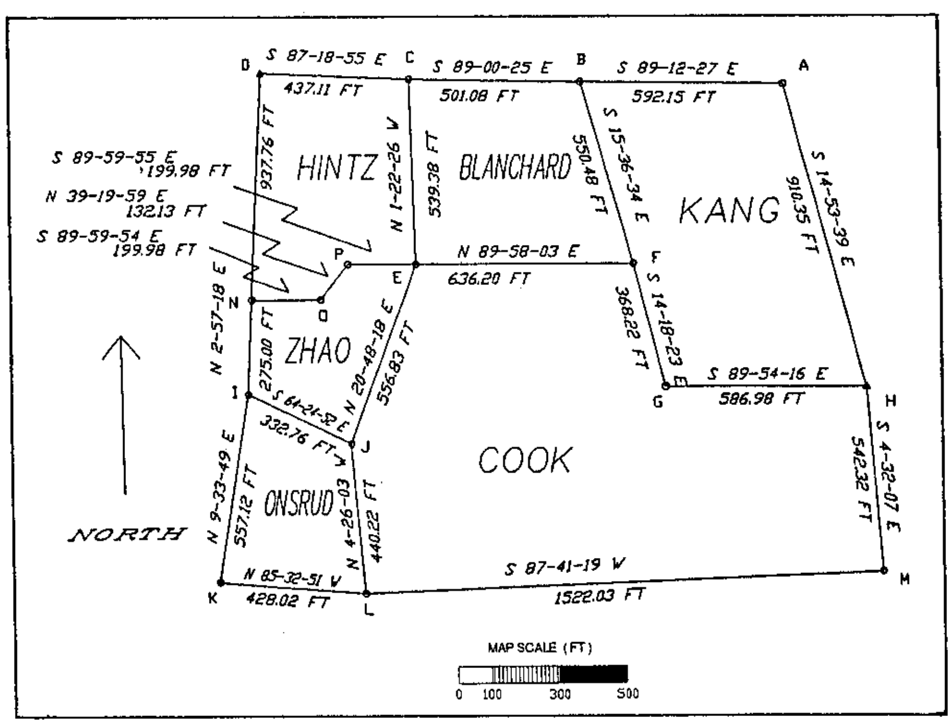


FIGURE 10.
Updated Cadastral Plat



upgrading the spatial information derived from tax maps to spatial information derived from real property surveys.

Because both approximate cadastral information from tax maps and accurate cadastral information from surveys are envisioned as being contained in the same GIS, means of identifying which category the data belong to must be developed. Numerous tagging methods are possible. Perhaps just maintaining two separate cadastral layers initially may be satisfactory for some purposes.

The above described system goes a long way in solving the temporal problem for surveying measurements in a GIS. However, it doesn't begin to address the temporal problems associated with the characteristics of the real property parcels (i.e., changes in land use, zoning, vegetation cover, erosion, etc.).

Another problem is how to upgrade other layers in the GIS that are dependent on the cadastral layer. For instance, presume that the initial cadastral layer in a GIS was formed by digitizing lines from tax maps. A sewer line is known to run down the center of a street and is so shown in another layer of the GIS. When the cadastral layer is updated using survey measurements rather than the digitized tax map information, the sewer line may now appear a substantial distance from the center of the street. GIS developers may want to consider developing methods of inputting data that will tie it to the cadastral layer. As the cadastral layer is updated, those other layers may then also be automatically updated (Kjerne and Dueker 1988).

The last issue raised is that providing accurate measurements between corners described by conveyance instruments does not in itself resolve boundary conflicts between adjoining real property owners. Developing a survey-based cadastral layer is likely to show the location, extent, and nature of such conflicts. For instance, in Figure 1, the cadastral layer clearly shows that the deed-described parcel owned by Onsrud and the deed-described parcel owned by Hintz are in conflict with each other. This conflict must be resolved as it always has been by resorting to the laws established by the U.S. legal system. The surveyors' role in this area will always remain to explain facts, provide evidence, express opinions, and aid the adjoining landowners in resolving the conflict in a legal forum for reaching a property line agreement.

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