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TECHNICAL NOTE

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Use of the Global Positioning System in the Field Recovery of Scattered Human Remains*

ABSTRACT: This study examines the Global Positioning System (GPS) as a tool for field mapping of scattered human remains or other materials in forensic investigations. Two aspects of the GPS are considered: (1) the level of accuracy that can be obtained using a mid-priced GPS unit, and (2) the effectiveness of using the GPS to map scattered materials. The positional accuracy of the GPS receiver was tested using a National Geodetic Survey (NGS) point located in Baton Rouge, LA. The utility of the GPS for mapping was investigated by setting up a mock field recovery and mapping the remains using both the GPS and traditional archeological methods. The results indicate that the positional error for a single location using GPS was less than one-half meter. However, when multiple positions were considered, the data produced on different days were not consistent. Further, the GPS receiver used in this study could not distinguish items in close association. Factors such as tree cover density, the proximity of the materials to structures or trees, and satellite positioning contributed to the erratic data. These results indicate that traditional techniques and photographs are still indispensable for mapping scattered remains or artifacts.

KEYWORDS: forensic science, forensic anthropology, global positioning system, geographic information system, field recovery

The field recovery of human remains is an essential role for the anthropologist in forensic investigations. Sites are often mapped and photographed to create a plan view of the remains *in situ* for medico-legal purposes. In situations where remains are widely scattered through animal activity or other processes, or where the landscape is topographically varied, hand-drawn maps are difficult to complete, even with the help of total stations. In such instances, the Global Positioning System (GPS) may be a useful tool. Researchers at the Louisiana State University Department of Geography and Anthropology have begun to use the GPS and Geographic Information Systems (GIS) for research and to assist with mapping scattered human remains and other materials in forensic contexts. The purpose of this article is to examine the level of accuracy that can be achieved using reasonably priced GPS technology and to explore the value of GPS in field recovery situations.

Materials and Methods

GPS receivers are available in prices ranging from less than one hundred to more than one hundred thousand dollars. The less expensive models, or leisure grade units, are less accurate than the more expensive mapping and surveying grade units. Additionally, these latter units can be complicated and time consuming to operate and may require specialized training to use. For the GPS to be practical in forensic investigations, the positional accuracy of the unit must be high; yet, the unit must also be affordable for limited budgets. For this study, we selected a hand-held unit that consisted of both a data collector receiver and a beacon receiver that provides "real-time" differential correction. The unit is the GeoExplorer® 3 Data Collection System (Trimble, Sunnyvale, CA) and Trimble's Beacon-on-a-Belt (BoB™ [Trimble]; Fig. 1).

To test the positional accuracy of the unit, we used a National Geodetic Survey (NGS) point located in Baton Rouge, LA. These points are defined and managed by the NGS as part of the National Spatial Reference System (NSRS). This system provides the framework for geographic and spatial information used throughout the United States for such things as the national defense system, boundary and property surveys, land record systems, and coastal management (1). The exact location of each NGS point is known; therefore, the positional accuracy of our GPS receiver was tested by calculating the difference between the coordinates generated by our unit and the known coordinates of the NGS point.

We chose an NGS point located in downtown Baton Rouge, LA. Data were collected without the beacon receiver and, thus, were not differentially corrected in the field. To collect data, the data receiver was held directly over the point, *c.* 5 ft above the ground. Two hundred and six readings were logged at 1 sec intervals; the final datum point consisted of an average of these readings. Although the coordinates generated in the field were uncorrected, we were able to correct the data differentially in the laboratory subsequently by using a base station in Pineville, LA. We then calculated the error for our unit using both the uncorrected and corrected, post-processed data.

To explore the value of GPS in field situations, a mock field recovery was set up at the Louisiana State University Law Enforcement Training Facility near Gonzales, LA. Figure 2 shows an overview of the location selected to place the elements. Multiple skeletal elements were placed randomly at eight positions, equally distributed between open and wooded environments.

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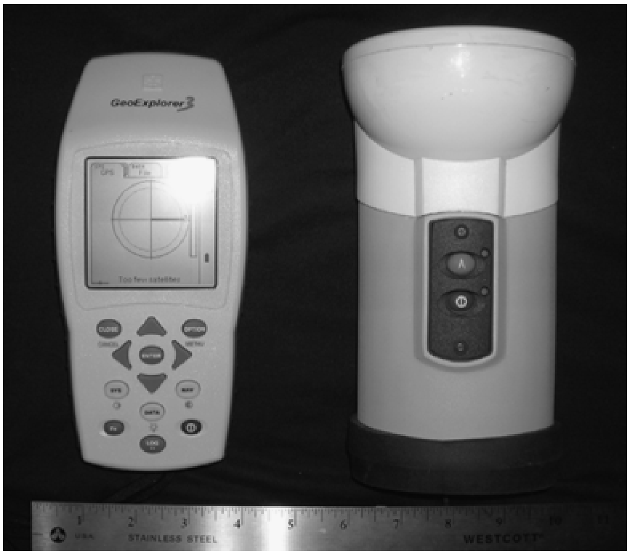

FIG. 1—*Global Positioning System data collector and receiver used in this study.*

GPS data were collected on two different days at each position. On the first day, data were collected with and without the beacon receiver, which produced both uncorrected and real-time corrected data. Later, the uncorrected data were differentially corrected in the laboratory using a base station in Pineville, LA. On the second day, only real-time corrected data were collected.

To collect GPS data, the receiver was held directly over the element or at the center of a cluster of elements, and *c*. 5 ft above the ground. For this aspect of the study, 100 readings were logged at 1-sec intervals at each position; the final coordinate for each position was based on an average of the 100 readings. Maps based on the GPS data from both days were generated using ArcView® GIS 3.3 (2).

Finally, the distribution of the remains in the mock field recovery was mapped by hand using traditional archeological methods. A datum point was chosen and the distance and direction of the remains from the datum were measured using 50-m tapes and a compass.

Results and Discussion

The results of the test for accuracy are displayed in Table 1. Without any correction, the GPS unit produced an error of 3.523 m, or *c*. 11.62 ft. Post-processed differential correction produced an error of 0.427 m, or *c*. 1.41 ft.

FIG. 2—*Overview of location selected for mock field recovery.*

TABLE 1—*GPS data collected for NGS point 17 B 012**.

	NGS Point (m): 17 B 012	LSU Data (m)	
		Uncorrected	Corrected with Post-Processing
North	3,370,007.778	3,370,009.263	3,370,007.375
East	673,728.399	673,730.437	673,728.375
Horizontal error		3.523	0.427

*These data were collected using the UTM coordinate system, Zone 15.
NGS, National Geodetic Survey; GPS, Global Positioning System; LSU, Louisiana State University; UTM, Universal Transverse Mercator.

The maps generated for the mock field recovery are displayed in Figs. 3–5. Figure 3 depicts the hand-drawn site diagram. This formalized version was created using Corel Draw® (3). In this diagram, the orientation of specific skeletal elements and their relationship with each other at each position are depicted.

Figure 4 displays a map for the three datasets generated on day 1 (e.g., based on the uncorrected, real-time corrected, and corrected, post-processed data). The original map was produced by ArcView® GIS 3.3 (2); however, Photoshop® (4) was used to clarify which points were taken at each position. The ovals encircle each position (numbered 1–8) and the three points generated for that position using the different datasets. As indicated in Fig. 4, the ultimate "location" of the element is different for each position number; however, as expected, the error is greater in the locations situated near or in the wooded area (positions five through eight).

Figure 5 displays the map comparing only the real-time corrected data generated on both days. As indicated in the figure, the data sets generated for each day are similar, with the exception of positions one, five, six, and seven. Positions five through seven are in the wooded area, which undoubtedly contributed to their larger errors. Position one, however, was in the open field. The source of the error for this position may be related to the position of the satellites or to the specific time of the day in which the data were collected. Because the number of satellites and their positions relative to each other in the orbit above the GPS data collector change continuously, the positional accuracy of the data also changes.

Traditional archeological mapping techniques include the use of tape measures and compasses, laser range meters, transits, total stations, or other ground-based surveying methods. While transits and total stations are highly accurate, they are cumbersome to transport and time consuming to set up and calibrate. For these reasons, we typically use tape measures and compasses in forensic field mapping. Thus, this study compares the GPS with hand-drawn rather than electronic techniques.

Regardless of which method is used, however, each of the traditional techniques typically requires a "line of sight" between the datum point and the location of the artifact being measured. When remains or artifacts are widely scattered by scavenging or other taphonomic processes, uneven terrain and/or tree density hinders the use and accuracy of all the traditional methods. This study investigates whether the GPS offers an accurate and viable mapping alternative.

The Navigation System with Timing and Ranging (Navstar) GPS has its origins in the United States military in the late 1950s and early 1960s. Since then, the relevance of the GPS and GIS has expanded to include many civilian applications, including navi-

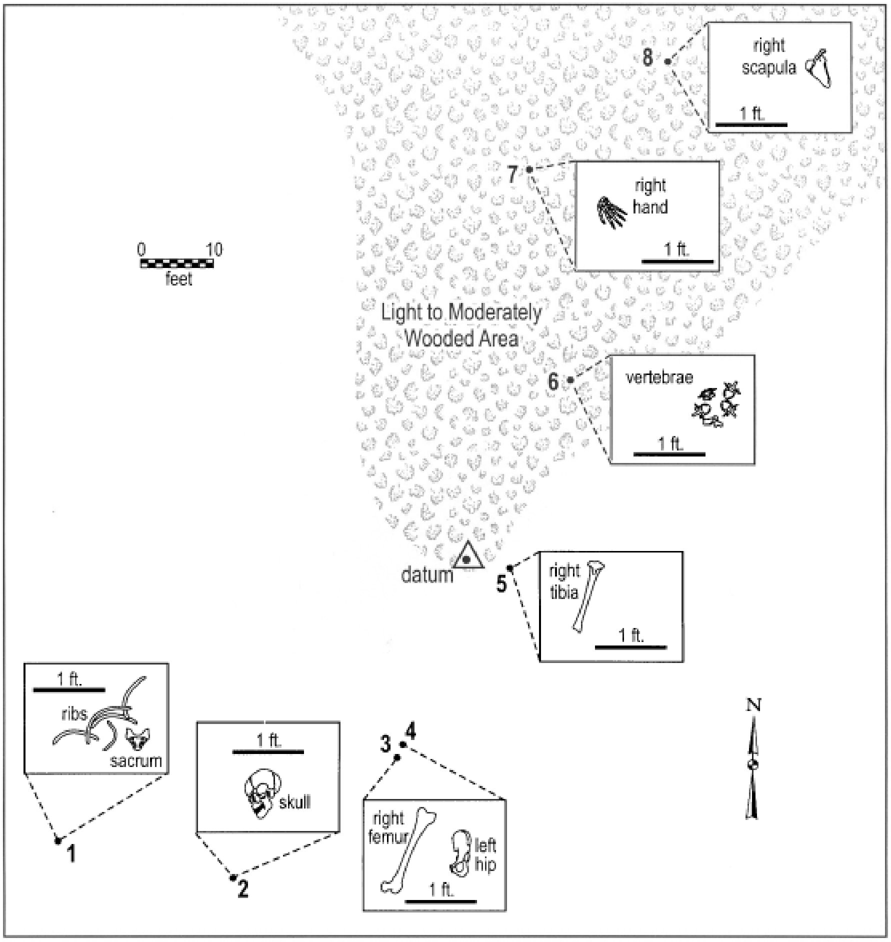

FIG. 3—*Formalized version of the hand-drawn site map for the mock field recovery.*

gation (land, sea, air), Intelligent Vehicle Highway Systems, disaster search and rescue (e.g., natural disasters, airplane or vehicle crashes, explosions, etc.), civil engineering projects, land surveying, recreational uses, archeological mapping, modeling and data management, and various others (5–7). In relation to forensic investigations, the GPS and GIS have been used for geographic profiling and mapping crime (8–10), as well as for studying the distribution of dumped and scattered human remains (11).

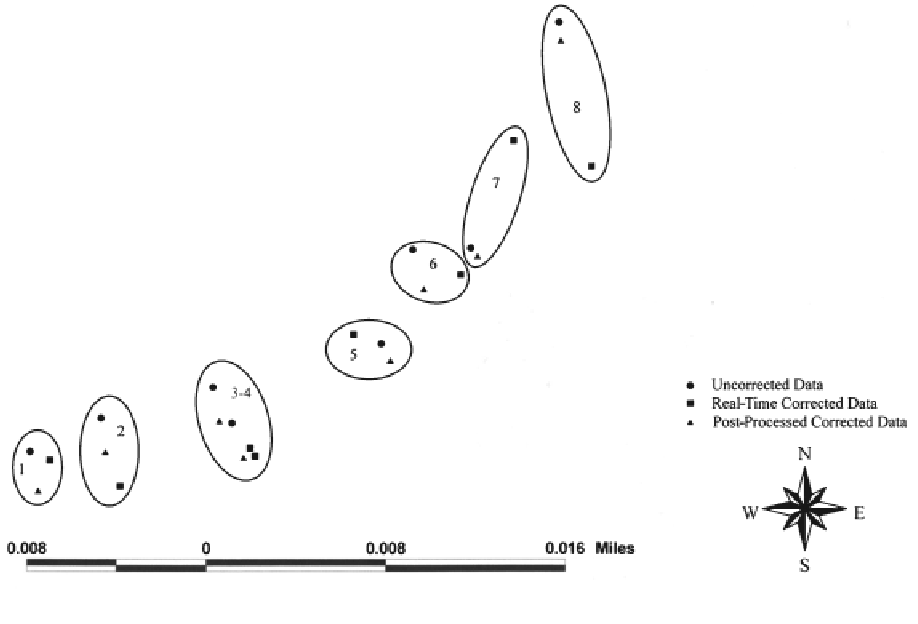

FIG. 4—*Map displaying the three datasets generated on day 1 of the mock field recovery.*

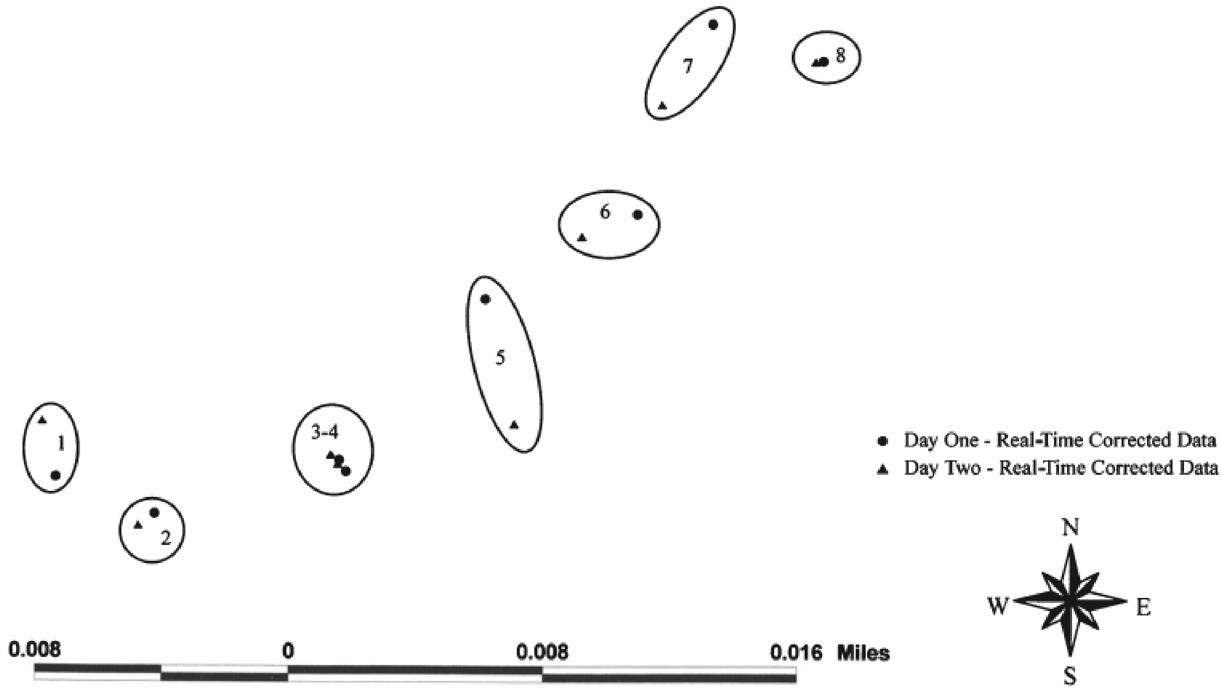

FIG. 5—*Map displaying the real-time corrected datasets generated on days 1 and 2.*

Additionally, recent paper sessions on geographic profiling and crime mapping at the 2006 annual meeting of the Association of American Geographers (12) and the National Institute of Justice (NIJ)-sponsored Eighth Annual Crime Mapping Research Conference in 2005 (13) attest to the increasing popularity of the field of forensic spatial analysis.

For the GPS to be useful in forensic investigations, whether for mapping scattered human remains or artifacts or for marking a single position (such as a burial, the original deposition site of a body, or a crime scene), the accuracy must be high. In general, the accuracy of GPS data can be affected by a number of different factors, including position of the satellites, atmospheric conditions, tree cover density, proximity of the artifacts to trees, buildings or other structures, and the receiver itself. Of these, the factor over which the anthropologist has the most control is the type of receiver he or she has to use. Leisure grade units are available and affordable; however, they tend to be less accurate. The unit selected for this study was thought to be a compromise: one that provided a relatively accurate reading but, at a cost of *c*. $4000 (including the BoB^{TM}), was not cost prohibitive. Our data indicated that this GPS unit was accurate to within one and one-half feet when data were differentially corrected using post-processing. Without differential correction, the accuracy of the unit was reduced to nearly 12 ft. For marking a crime scene or burial location, an error of one and one-half feet is not unreasonable. The marked area could be relocated without much difficulty, even if decades had passed. However, for mapping scattered human remains, even this small error (while not assessed statistically) produced noticeably different results (refer to Figs. 4 and 5).

Of the remaining factors that affect accuracy, satellite position offers the anthropologist some measure of control under specialized circumstances. Because the orbits of all 24 satellites that make up the space segment of the Navstar GPS are known, their position relative to each other at certain times of the day is also known. This information, along with other data, is included in almanacs that can be downloaded directly from the satellites by the GPS receiver (6). In forensic situations, if the day and general location (i.e., city or parish) of the field recovery are known in advance, the anthropologist, by utilizing the information included in almanacs, can plan to collect data during the times in which the satellites are optimally positioned.

The other factors that affect accuracy (tree cover density, atmospheric conditions, and the location of a deposition site) cannot be controlled. In situations where these factors are problematic, the accuracy of marking a single location can be increased by collecting readings from multiple positions for the same location, post-processing (i.e., differentially correcting) the data, and subsequently calculating the spatial average of all corrected positions. The accuracy of the corrected spatial average increases as more positions are collected. The disadvantage to this solution is that the data collection process becomes more time consuming as well. Additionally, this solution (computing the spatial average) could not work for *mapping* scattered remains, not only because of the increased time component but also for logistic reasons. In a situation where obtaining GPS data is already problematic, the attempt to collect additional data in order to compute the spatial average for each position in which an artifact is located would be difficult and impractical.

For mapping scattered human remains or artifacts, both traditional archeological techniques and the GPS offer certain benefits and drawbacks. Assuming conditions are favorable (i.e., the line of sight is present), traditional techniques allow the anthropologist to differentiate artifacts or remains that are located close together. With the GPS, elements located within 2 ft of each other may not be distinguishable. Furthermore, with a hand-drawn diagram, the anthropologist can record (in addition to photography) the position and orientation of the remains *in situ*; these details cannot be captured by the GPS unit.

On the other hand, data collected by GPS units are digital, georeferenced (i.e., based on a common coordinate system such as the

Universal Transverse Mercator (UTM) grid or on geographic coordinates expressed in degrees latitude and longitude), and can be uploaded to the computer where they can be analyzed and mapped using various GIS programs. Analysis of such data can reveal trends of skeletal element or artifact distribution according to additional geo-referenced information, including the environment, landscape, and other natural or man-made features (11).

Conclusion

Mapping scattered human remains or other artifacts during field recovery can be challenging due to the distance over which the remains are dispersed as well as to the varied environments in which the remains are found. Traditional archeological methods may be difficult to use due to time constraints in setting up the equipment properly or because of the terrain. This project tests whether or not the GPS offers an accurate and reliable alternative for mapping scattered artifacts.

We found that reasonable accuracy can be achieved using a moderately priced unit and, thus, GPS offers an excellent means of marking single location such as a burial site or a crime scene. Additionally, data produced by GPS can be analyzed using GIS for geographical or environmental trends in remains dispersal or site deposition. However, the use of GPS for mapping scattered remains in close association (i.e., within approximately one and one-half feet) was not possible with the type of receiver used in this study. In such instances, traditional archeological surveying methods are still indispensable.

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