

# Terrestrial Lidar and GPR Investigations into the Third Line of Battle at Guilford Courthouse National Military Park, Guilford County, North Carolina

Stacy Curry, Roy Stine, Linda Stine, Jerry Nave, Richard Burt and Jacob Turner

**Abstract** A joint geophysical and archaeological field school was conducted near the third line action at the battle of Guilford Courthouse, located at the Guilford Courthouse National Military Park, Greensboro NC. The location of the third line is under debate by historians and archaeologists. A ground penetrating radar (GPR) survey revealed a linear feature approximately 50 cm in depth, varying in width and trending north south for approximately 68 m before entering a heavily wooded area. Excavation of a narrow trench towards the end of the field season revealed a colonial surface, possibly a road or gully, covered in fill dirt. Both a road and a gully have been discussed in the literature, and their discovery would yield important clues to the location of the third line. The surface of this buried feature was slightly concave. A team from Auburn University joined UNCG and NC A&T SU researchers with a terrestrial laser scanning (TLS) survey to see if a highly detailed elevation map could trace the surface manifestation of the feature into and through the wooded area. The results of the research demonstrate the successful exportation of GPR data into three dimensional point clouds. Subsequently, the converted GPR points in conjunction with the TLS were explored to aid in the identification of the colonial subsurface. The TLS dataset has the capacity to discern the concave surface found in the dense overgrown and obstructed wooded area which could be a continuation of the subsurface feature seen in the GPR data.

---

S. Curry (✉) · R. Stine · L. Stine · J. Turner  
The University of North Carolina at Greensboro, Greensboro, NC, USA  
e-mail: securry@uncg.edu

J. Nave  
NC A&T University, Greensboro, NC, USA

R. Burt  
Auburn University, Auburn, AL, USA

## Introduction

Guilford Courthouse National Battlefield Park (GUCO) is the site of a pivotal 18th century Revolutionary War battle. In March of 1781 General Cornwallis leading the British army engaged American forces made up of militia units from North Carolina and Virginia as well as Continental line troops near Greensboro North Carolina (Fig. 1).

The courthouse was pivotal in the action over the contested land. There is agreement as to the general location of the first two lines of battle (Fig. 2).

The last action of the battle or third line was located near the courthouse. From this location General Greene directed the battle and finally had his army retreat along a north south trending road. While technically a victory for the British army the losses suffered in the battle caused its commander General Cornwallis to leave the Carolinas and move into Virginia where he was later defeated at Yorktown. The landscape of the Park from colonial settlement and county courthouse to battlefield to farm to historic preserve surrounded by housing developments has seen modification and reuse. The exact locations of the courthouse and the “retreat” road are an ongoing debate by various scholars and would help enhance the interpretation of this site (Babits and Howard 2009; Baker 1995; Coe and Ward 1973; Durham 2004; Cornelison et al. 2007; Hatch 1970; Hiatt 1999; Ward and Coe 1976; Stine and Stine 2013; Stine et al. 2003). The discovery of the courthouse location, the retreat road or other subsurface features may lead to an accurate placement of the third line of battle.

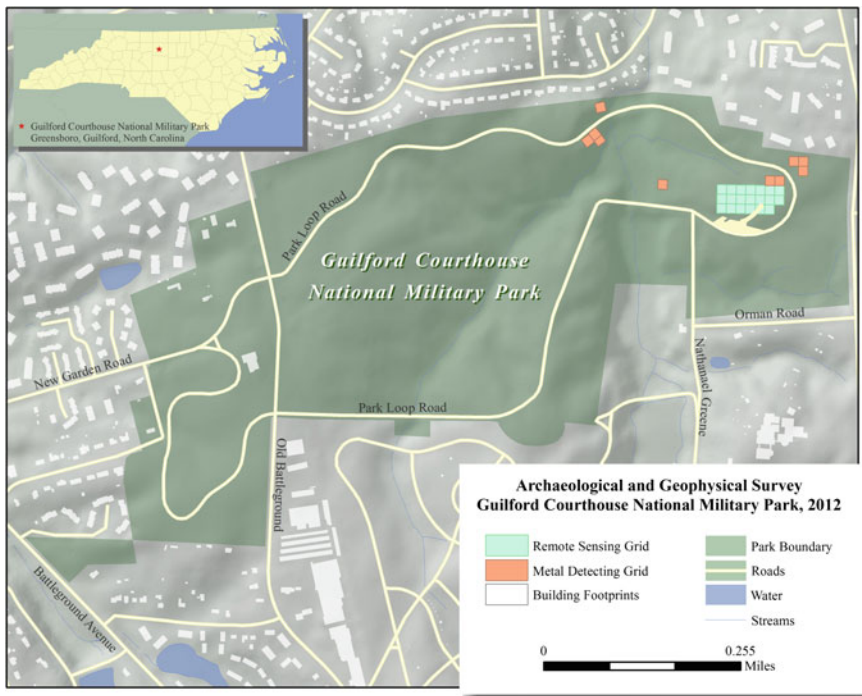


Fig. 1 Guilford Courthouse National Military Park (Dr. Elizabeth Nelson)

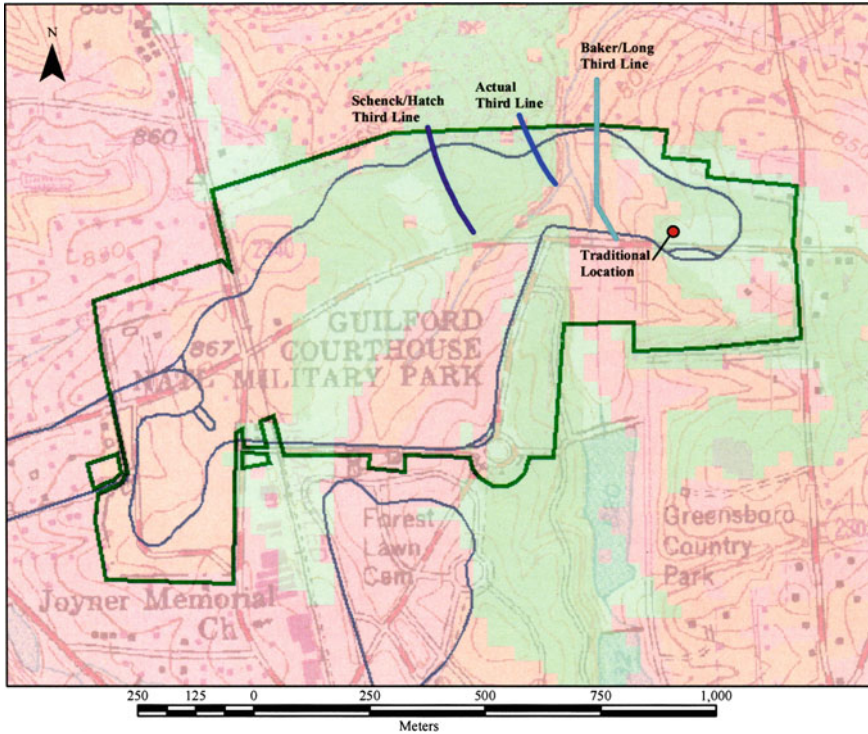


Fig. 2 Disputed location of the third line (Cornelison et al. 2007)

The environment surrounding one of the suspected locations of the courthouse is partially accessible, with mowed grass transitioning into secondary growth brush and trees with an undulating topography. Aerial and satellite imagery and traditional airborne Lidar have proved ineffective at determining the microtopography in this type of environment. Guilford Courthouse’s unique blend of environmental conditions, both woody and grass provide a testing ground for utilizing other such methods of mapping similar forested sites. Applying the terrestrial laser scanning to certain subsets of the site can begin to answer questions about the landscape obscured by the woody environment (Fig. 3).

The overarching question of the larger research project involves the potential to combine multidimensional datasets from multiple sensors to produce an effectively fused above and below ground dataset. Drawing on historical archaeological data, GPR, TLS point cloud, and Total Station datasets, this paper focuses on the methods and results of the digital data fusion. In addition, the discovery and implementation of the most effective strategies to handle research sites with heavy vegetative cover and/or obstruction with regards to sensors selections and data fusion methodology are explored. Discovering the most beneficial way to visualize fusion datasets to aid in understanding historical landscapes is a major thrust of this study.



**Fig. 3** Wooded study site

## Literature Review

Geophysical surveys are one of the critical sources of subsurface data in this research. The roots of archaeological geophysics lies in its ability as a prospection tool to locate map and produce images of buried cultural materials (Conyers 2010). Non-invasive investigations of subsurface anomalies through geophysical surveys can provide archaeologists with valuable information prior to, or in-place of, the non-reversible processes of excavation (Yu-Min Lin et al. 2011). The continued application and development of geophysical coverage for archaeological assessment has begun to introduce an alternative perspective into regional, or landscape archaeology (Kvamme 2003). Such surveys provide information on the structure and organization of a site enabling the study of spatial patterns and relationships relevant to research questions. In addition to the large-scale perspective of the site, geophysical survey results also provide a high-resolution focus on individual site features (Watters 2012). Applying advanced acquisition and processing techniques can not only map the spatial extent of buried features precisely in three-dimensions, but potentially can determine specific material properties of subsurface features such as stone, earth or brick. When these types of analysis are incorporated within a historical framework, ideas about the past can be tested and studied in ways not possible before (Conyers 2010).

Ground Penetrating Radar (GPR) was chosen from the geophysical surveys employed in this research to be used as the subsurface dataset. GPR transmits an electromagnetic pulse and measures a reflected signal that is dependent upon the dielectric properties of subsurface material. With GPR, the potential for the reconstruction of high-resolution 3D data visualizations of the composition of the subsurface is possible (Yu-Min Lin et al. 2011). Identifying discontinuities in the subsurface, including stratigraphic contacts, walls, house or pit floors, rubble, or midden deposits, causes the radar energy to be reflected back to the surface (Kvamme 2007). The velocity of this energy varies greatly, depending on dielectric properties of the subsurface materials. If velocity can be estimated, then return times of echoes from pulses give information on depth, while amplitudes indicate something of the nature of subsurface changes (Kvamme 2007).

An additional source of data for the visualization of above and below ground surface features includes the exploitation of point cloud data. A point cloud is a collection of discrete three-dimensional locations (points) that can have additional metadata associated with each record. Point clouds appear realistic to even the most casual observer because of their three-dimensional nature. Active scanning technologies generate their own scanning energy and can record and even discover archaeological features at both site and landscape scales. These systems send out discrete pulses of light and record both how long it takes those pulses to return and how much of the original energy comes back. That information, when combined with data about where the sensor is positioned and how it is oriented with respect to the real world is used to construct the point cloud. Each point in the cloud represents a location where the light pulse reflected off of a surface (White 2013). The active system that is used in this research is the terrestrial laser scanner (TLS). The term “laser scanning” describes any technology which accurately and repeatedly measures distance using laser pulse, by precise measurement of time needed for the laser pulse to travel from the object and back and transforms these measurements into a series of points, or a point cloud, from which information on the morphology of the object being scanned may be derived. (Mlekuz 2013) Terrestrial laser scanning (also known as ground-based LiDAR) is increasingly used as a method of collecting spatial data, and when supported by digital photogrammetry, can render quantitatively accurate and visually impressive representations of land surfaces (Entwistle et al. 2009). Terrestrial laser scanning enables the researcher to quantify and integrate previously implicit knowledge-based field observations of topographic setting into a framework for interpreting an archaeological site and its characteristics (Entwistle et al. 2009).

Ultimately, given enough observations of a densely-covered landscape by an active scanning system, some inevitably come from the ground beneath or next to the cover and can be used in conjunction with an extrapolation process to reconstruct the ground surface. The more ground observations you have, the better the surface reconstruction (White 2013). The 3D laser scanning data and GPR survey information also share common characteristics in that both can be broken down into a series of spot readings or sample rates, in other words the data can be treated as points. This is most familiar as the basic form of laser scan data, the point cloud.

However for GPR the archaeological deliverables mostly come in the form of 2D images. By producing the results of the GPR as a list of X and Y coordinates based on the relative grid positions and sample spacing, and treating the calibrated depth as a Z the data could also be interpreted like a point cloud. In this case the signal response then becomes the Intensity value just like the reflection of the laser from the scanner (Watters 2012).

An essential part to this research is the data fusion and integration of all data collections. Construction of multi-scale models can be time-consuming, but this is offset by the following advantages: much improved regional context that is immediately accessible visually when analyzing and interpreting more localized field datasets (Jones et al. 2009). Employing a combination of methods over a survey area can help provide information as to the nature, or material, of an anomaly, thus providing insight for site interpretation. Mapping the distribution of disturbances over a site can assist in the recognition of such disturbances generated through cultural activities revealing the spatial distribution and association with site features (Kvamme 2003). These independent data sets are combined in 3D space through their geospatial orientation to facilitate the detection of physical anomalies from signatures observed across various forms of surface and subsurface surveys. The data types are variable in nature and scale, ranging from 2D imagery to massive scale point clouds (Yu-Min Lin et al. 2011). The data fusion process is able to establish interrelationships and patterns between multidimensional data sets, and therefore improve the identification and interpretation of surface and subsurface traces, that may otherwise go unnoticed (Ogden et al. 2009).

Geophysical surveys have been employed on a variety of locations at GUCO (Cornelison et al. 2007; Cornelison and Groh 2007; Stine and Stine 2013). A variety of subsurface anomalies and features have been located. Because of its protected status as a National Park few of these items have been excavated. Most recently Stine and Stine (2013) conducted a magnetometer survey which covered 4675 m<sup>2</sup> and the GPR survey that covered 2714 m<sup>2</sup> in an area thought to be the courthouse. Almost 160 anomalies were recorded and mapped. Stine and Stine were granted a permit to excavate in a specific location within the park. It is highly probable that 2–4 new structures (foundations) were located; one was excavated and showed to be a stone foundation. One of the most interesting features located by the GPR was a subsurface anomaly between 45 and 50 cm in depth and trended north/south for over 30 m before entering a heavy shrub and forest area with dense secondary growth. In the open area there was a slight depression on the ground surface. This area was near what Ward and Coe (1976) reported to be the Americans' retreat road. The small trench was excavated over the anomaly. There was a light scattering of recent material on the surface of the excavation then sterile clay fill for a depth of over 45 cm. The excavation revealed a tannish brown lens of sandy soil with Revolutionary War period ceramics such as pearlwares and creamwares as well as lead sprue, copper disks; and a piece of swan shot all falling within the colonial period (Stine and Stine 2013). It could not be determined if this was the historic retreat road based on the results of the 2011 field season.

At this same location the goal is to examine the microtopography to search for any deformation related to a possible retreat road and/or gully that were prominent features in the battle but have since disappeared from the landscape. A comprehensive geophysical survey using ground penetrating radar (GPR) combined with a terrestrial laser scan (TLS) helps identify key elements in modeling this historic landscape. This provides not only provide a more comprehensive view above and below the surface of this feature, but demonstrates a new method of fusing datasets from differing sensors.

The discovery of the third line would help place other military units and ultimately lead to the location of the courthouse, a major goal of the 2011 project. Using various remote sensing and geophysical surveying techniques the road or gully may have been identified in a comprehensive three dimensional visualization. The fusion of datasets from very different sensors provides a new way of examining the cultural and physical landscape thought to be the third line. As an emerging research topic this investigation demonstrates the capability to discover landscape features through nondestructive means. The implementation of methodology for the visualization of three dimensional data from different types of sensors; Ground Penetrating Radar (GPR) and Terrestrial LiDAR (TLS) begins to illustrate the usefulness of combining such data.

## Methodology

The GPR survey was conducted using a GSSI ground penetrating model DC 3000 equipped with a 400 MHz antenna was used to conduct the site survey. The total area coverage for the entire study site was 2714 m<sup>2</sup> with standard transects. Transects were collected in 50 cm with a dielectric constant of 8 and in 16 bit format. All pre-fusion processing was completed in Radan 7 software. A linear feature approximately 50 cm in depth, varying in width and trending from north to south for approximately 68 m before entering a heavily wooded area was identified in profile. In Fig. 4 the red box indicates the area of interest. The higher the amplitude the return from the GPR signal the more intense the coloration shown. A linear feature that extends to the north begins to emerge with a high amplitude signature (Fig. 5).

For the TLS scanning help was provided by the team from Auburn University using a Leica C10 laser scanner. The scanner ran six 360 × 270° scans. Scan setups were spaced anywhere from 60 to 150 ft apart, depending on the density of the forest surrounding the scanner. The scans were registered together using seven targets, a number of which were entered into the scanner at each setup. In order to improve accuracy of the terrain measurements, the scanner was placed on a seven foot high tripod. The increased height reduced the angle of the return laser and lessened shadows from low-lying ground cover. The data were initially pre-processed in Leica Cyclone software. The point cloud that is created was interpreted into x, y, z coordinates (Fig. 6).

**Fig. 4** Excavation (2011) of road/gully potential location



In addition to GPR and TLS data collections, standard total station mapping was also conducted for registration of the two datasets. The deployment of a traditional total station survey provides accurate positioning for both data collections and for successful data fusion. A survey grade Topcon GR-3 Global Positioning System (GPS). The GPS antenna is capable of Real-Time kinematic (RTK) survey. The RTK survey method utilizes two GPS antennae: a stationary base that is set up over a point with known coordinates, and a manned, moveable, rover that optimally



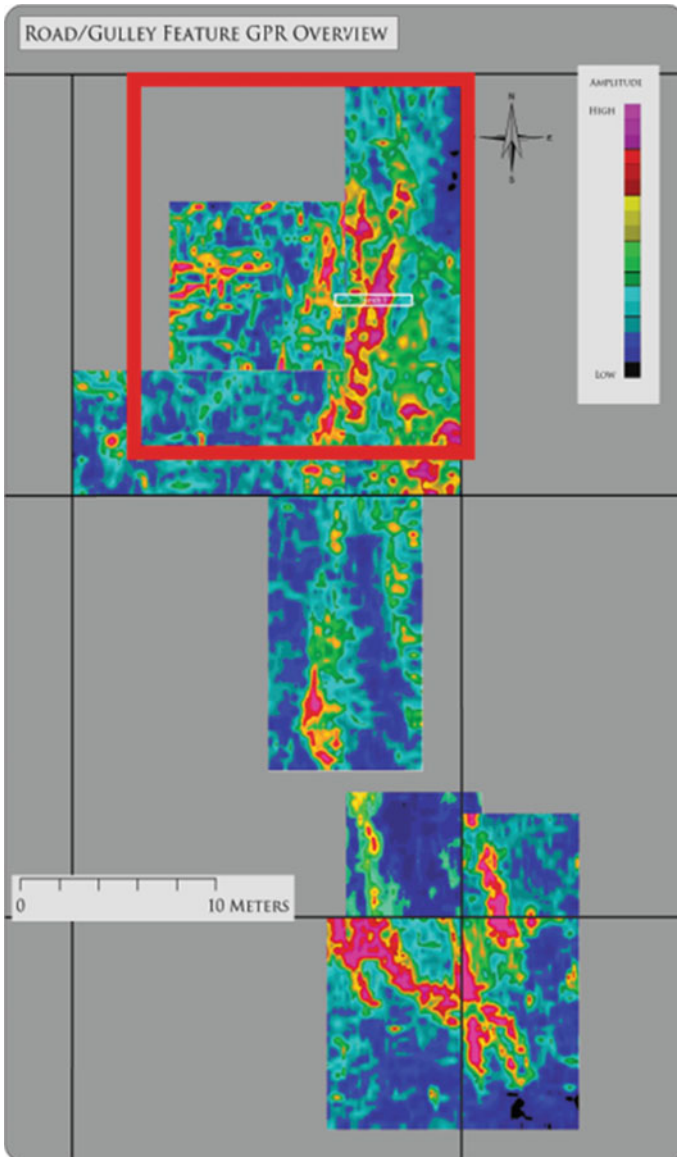


Fig. 5 GPR data collection

receives the same satellite signals as the base, but also receives instant correction via a radio link to the base antenna. This method enables a high level of positional accuracy that other GPS units cannot achieve. A traverse was begun by setting a GPS base station over Lincoln Monument—a brass disk established by the North Carolina Geodetic Survey—using the Lambert Conformal Conic State Plane (feet)



**Fig. 6** Leica C10 TLS

coordinates referenced to NAD83/86. A new datum point was then established with the rover positioned over semi-permanent marker such as a nail. The National Park Service requires all coordinate information in be completed in the Universal Transverse Mercator (UTM) projection and shown in meters. The projection and coordinates (including X, Y and Z) were, therefore, shifted to the UTM Zone 17, NAD83/86 using ArcGIS 9.3. Once the datum was established all additional datums, grid layouts and location points were completed using a Topcon GTS 233W total station with a Recon data collector equipped with Survey Pro 4.1.5.

The ground penetrating radar data is processed using GSSI Radan 7 software to normalize surface, velocity, and other standard corrections. After examining in the profile, an area of interest emerge indicating the road/gully feature previously discussed. These areas are then isolated by depth and are exported in the three dimensional formatting of xyz. Where each depth slice of 10 cm to 1.50 m is

exported with UTM NAD83 coordinates are represented as the x and the y with z being the elevation and a further attribute of amplitude return from the GPR antennae. In Fig. 7 the yellow box indicates the area of the potential gully/road. In Fig. 8, the area is isolated to show the point cloud derivative from the GPR used for exploration of fusion methods.

The terrestrial laser data was preprocessed at Auburn University in Leica Cyclone propriety software package. Once receiving the dataset from Auburn, the

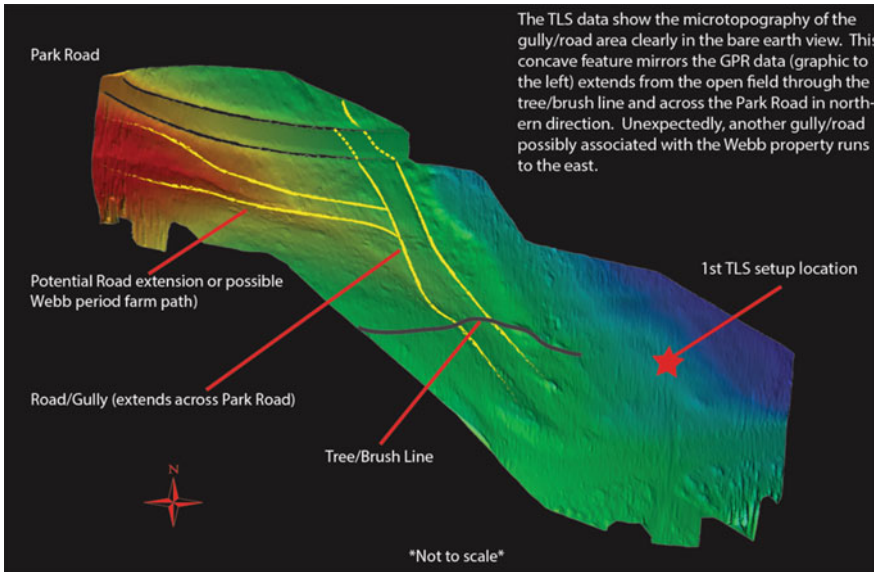


Fig. 7 TLS derived digital elevation model and interpretation

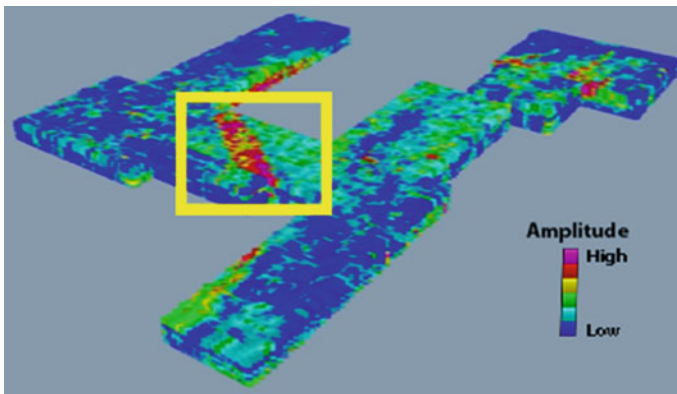
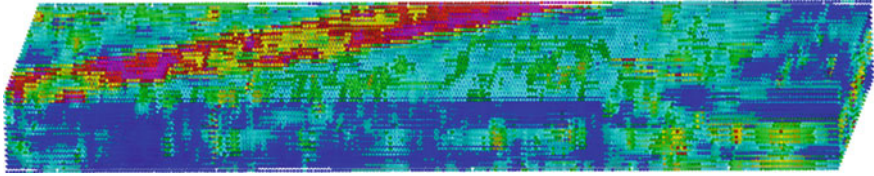


Fig. 8 GPR in point cloud



**Fig. 9** GPR in point cloud of possible portion of road/gully

data were converted to xyz formatting using Bentley Pointools. Since the fusion is based on the geographic coordinates of both the TLS data needed both georeferencing and registration of coordinates in order to fuse with exported GPR datasets. The TLS data had to be further clipped, gridded, and divided into multiple smaller subsets in order to be able to work within the computing power restraints. Georeferencing results in ESRI's ArcMap and LAStools proved unattainable due to computing power and software capability to handle such point clouds. Further attempts were taken Civil 3D CAD software and proved difficult. However, using the opensource software Cloudcompare allowed for partial alignment of small sections using previously collected total station ground points. Figure 9 illustrates the potential road area in the TLS point cloud.

The research goal was to determine if we could visualize in the datasets the road and attempt to fuse the GPR and TLS data together. Using Golden Software's Voxeler software package, both datasets can be imported multiple individual files to create three dimensional point cloud. Taking a small area of the identified road feature and adding both sets of point clouds a preliminary proof of concept is achieved.

## Results

Initial results for the development of methods to export and fuse GPR and TLS data and create three dimensional files for modeling using Voxeler software proved successful. After exportation and alignment procedures were completed, Voxeler provides quick and easy to use visualization tools. The subsurface colonial road/gully can be visualized along the more open area of the site with its surface manifestation (the slight depression) mapped. Using the TLS data to follow the concave surface into the wooded area also proved successful. Figure 10 depicts the preliminary results from the data fusion using the coordinates and elevation as the attributes to match each point. The yellow box indicates the road/gully area of interest that appears in both datasets (Fig. 11).

Working in wooded areas are challenging for these surveys. GPR data are attenuated by trees roots and moving the antenna through thick brush is not possible. In some instances cutting brush is an option but not on a protected site. The wooded areas surveyed contain dense brush and leaf litter, the methods using laser scanning resulted in an highly effective strategy for tackling such obstructed sites. The TLS



Fig. 10 TLS point cloud highlighting the potential road/gully

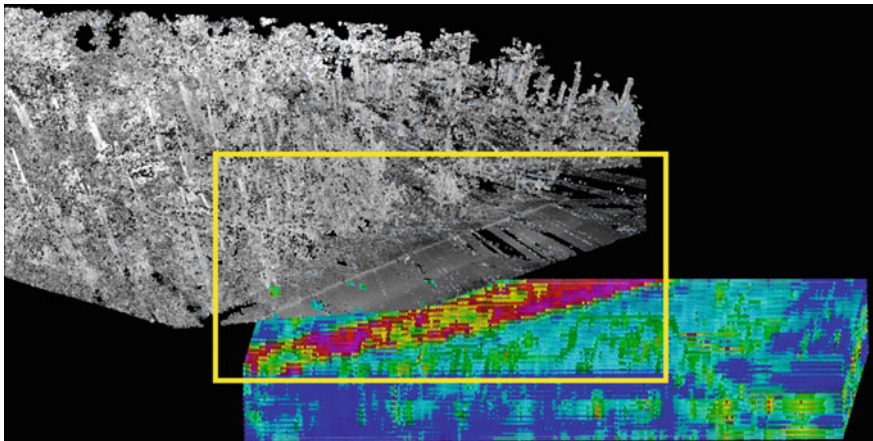


Fig. 11 Data fusion of GPR and TLS datasets

data and post-processing measures did show a north south trending concave surface within the wooded area. The authors cannot of course state that this is a surface manifestation of the subsurface feature without excavation. The data and methods do however point to specific locations to test in the future. Methods from this research highlight the ability to take two different sensors and use them to examine subsurface and above ground landscape simultaneously. A further benefit from the research is the ability to achieve results from enormous datasets while operating with low level computing power found in traditional computer labs. Also, the results show what can be gained while working with opensource and low cost computer packages.

## Discussion

This research was to design to develop methods to fuse subsurface data collected by GPR with surface information provided by the TLS. Literature is lacking in methods to take these two widely used data sets and combine them to visualize the landscape above and below ground. Difficulties encountered by the authors included learning and integrating the variety of software used by the different researchers. The size and resolution of the datasets created, seamless transfer of the data created processing and storage issues on our computers. Each sensor required a variety of differing preprocessing software before the datasets can be exported for fusion to occur. The processes derived are considered as an initial step which we hope to develop in the future.

The research reveals that new and improved methods are needed to enhance future similar endeavors. Repeat collects and subsequent point cloud collects are needed to generate the needed coverage for the data fusion process. Alignment issues need to be further accounted for due to the lack of proper software and georeferencing. Difficulties arose due to the numerous software packages and multiple iterations were needed in order to export, fuse, and visualize all data. Topographic correction of the surface layer from the GPR data are needed to better represent the nature of the surface. Future efforts will involve building on the methods developed during this research and applying to other historic sites with spatial research questions. A critical component of future work would assess the accuracy of the point to point data fusion through the application of geostatistical methods. The value of future research would be to develop additional methods to address in the field registration, and enhanced processing of datasets through access to more powerful possibly supercomputing opportunities. Ultimately the authors would like to create an immersive dataset creating a virtual landscape of the historic site where the researcher and community can virtually navigate the site and examine all the features above and below ground.

The second research goal was to investigate the extent of the subsurface feature as in was seen to the open area of the site. Walking into the wooded area the concave feature quickly disappeared, thus ruling out the use of traditional total station survey, (it's hard to map what you cannot see!) The use of the TLS and the generated point cloud allowed the researches to identify areas that seemed to be a continuation of the subsurface road/gully. Hopefully future test excavations will be able to verify or reject this possibility.

## Conclusion

This research investigated methods to fuse GPR and TLS data. The data are quite different one is generate from a radio wave the other from a light source. One arrives with discrete x, y, z coordinates the other must have the coordinates

generated from a time slice. The initial work in this area has proved successful resulting in a fused dataset showing below ground, surface and above surface 3D points. The research also was successful in delineating a surface feature, easily seen in the open area but hidden by dense shrubs and leaf litter in the wooded part of the site. The TLS data collection and post-processing indicated the possible continuation of the feature and will hopefully be verified by future excavation.

This research investigated methods to fuse GPR and TLS data. The data are quite different; one is generated from a radio wave the other from a light source. One arrives with discrete x, y, z coordinates the other must have the coordinates generated from a time slice. The initial work in this area has proved successful resulting in a fused dataset showing below ground, surface and above surface 3D points. The research also was successful in delineating a surface feature, easily seen in the open area but hidden by dense shrubs and leaf litter in the wooded part of the site. The TLS data collection and post-processing indicated the possible continuation of the feature and will hopefully be verified by future excavations.

The data fusion of the sensors allowed for detailed three dimensional above and below ground surfaces. The techniques have shown the ability to document archaeological features from more than one perspective and where traditional techniques (shovel testing and pedestrian survey) have proven less successful. The identification of a buried surface feature (road/gully) combined with the vague surface elements of the feature continuing in the woods creates an historic landscape. The potential of this fusion means that future excavation of the area should reveal the exact nature and direction of the feature. Both the gully and the road are keys to unlocking the location of the elusive third line of battle at Guilford Courthouse; giving archaeologists, historians and geographers a more complete picture of the battlefield landscape.

The authors are continuing the application of multidimensional data fusion methodology from GPR and TLS to a variety of other archaeological and historical sites. The techniques are transferrable to any location that is looking to view above and below ground archaeological features and make them visible for interpretation in the context of the landscape. For example, current research is being conducted at the House in the Horseshoe (Alston House) State Historic Site located in Sanford, NC. The Alston house is an 18th century property with a complex history of land use. The property was the scene of skirmish between North Carolinians loyal to the British crown and those in favor of independence. Unlike Guilford Courthouse Battlefield, a still extant structure is present with the original bullet holes. Current work suggests that the visible topography has been altered. In the 19th century, the site was a robust plantation of a NC governor, including his household and the enslaved, encompassing much more acreage. The site provides a unique opportunity to study the landscape changes brought about over time by these varying scales of the property's uses.

Fusion techniques at the House in the Horseshoe include an extensive geophysical survey using GPR, gradiometer and resistivity/conductivity. This survey has already provided insight into the buried features located on the property and results were coordinated with archaeological testing. In addition to the geophysical

survey methods, the House in the Horseshoe site presents an opportunity to examine the historic structure of the Alston House through passive scanning. The Alston House is used to test the hypothesis that using a SLR digital camera to capture multiple images of the Alston House can provide an accurate point cloud. The structure is imaged through acquisition of multiple photos taken of the house from multiple angles. Using software such as Structure for Motion (SFM), AGIsoft Photocan, and Meshlab a three dimensional point cloud can be created to create a realistic model. The goal is to implement this technique and then test the accuracy of the point clouds to the real world points from a total station survey. Goals of the project would be to then compare the digital photography techniques to a traditional TLS collection, perform accuracy assessments, and ultimately conduct the data fusion process incorporating the geophysical survey data. The specific techniques defined in this research are being refined for different historical landscapes with different research questions. Archaeologists, geographers, and remote sensors interested in landscape analysis will find these techniques informative and relatively inexpensive. Fusing a wider selection of sensing data will hopefully allow for the discovery, identification and interpretation of below ground features and their surface interactions.

## References

- Babits, Lawrence and Joshua Howard (2009). *Long, Obstinate, and Bloody the Battle of Guilford Courthouse* The University of North Carolina Press, Chapel Hill, NC.
- Baker, Thomas E. (1995). *Redeemed From Oblivion: An Administrative History of Guilford Courthouse National Military Park*. Manuscript on File, Guilford Courthouse Military Park, Greensboro.
- Coe, Joffre L. and Trawick Ward (1973). *Preliminary Archaeological Tests Guilford Courthouse*. Research Laboratories of Anthropology, University of North Carolina, Chapel Hill.
- Conyers, L. B. (2010). Ground-penetrating radar for anthropological research. *Antiquity*, 175-184.
- Cornelison, Jr., John E. and Lou Groh with Greg Heide, Tammy D. Cooper, Guy Prentice and David Lowe contributors (2007). *Battle Lines and Courthouse: Archaeological Survey and Testing at Guilford Courthouse National Military Park Greensboro, North Carolina The 1995, 1997, and 1998 Field Projects*. National Park Service, Southeast Archaeological Center, Tallahassee, FL.
- Durham, John Lloyd (2004). *Historian's Report on the Location of Guilford Courthouse*. MS on file, Guilford Courthouse National Military Park. August 2004.
- Entwistle, J. A., McCaffrey, K., & Abrahams, P. W. (2009). Three-dimensional (3D) visualisation: the application of terrestrial laser scanning in the investigation of historical Scottish farming townships. *Journal of Archaeological Science*, 860-866.
- Hatch, Charles E., Jr. (1970). *Guilford Courthouse and Its Environs*. United States Department of the Interior, National Park Service, Washington, D.C.
- Hiatt, John (1999). *Guilford Courthouse National Military Park Cultural Landscape Report*. Manuscript on file, National Park Service, Guilford Courthouse National Military Park, Greensboro.
- Jones, R. R., McCaffrey, K., Clegg, P., Wilson, R., Holliman, N., Holdsworth, R. E., . . . Waggott, S. (2009). Integration of regional to outcrop digital data: 3D visualisation of multi-scale geological models. *Computers & Geosciences*, 4-18.



- Kvamme, K. L. (2003). Geophysical Surveys as Landscape Archaeology. *American Antiquity*, 435-457.
- Kvamme, K. L. (2007). Integrating Multiple Geophysical Datasets. In J. Wiseman, & F. El-Baz, *Remote Sensing in Archaeology* (pp. 345-374). New York: Springer.
- Mlekuz, D. (2013). Skin Deep: LiDAR and Good Practice of Landscape Archaeology. In C. Corsi, *Good Practice in Archaeological Diagnostics* (pp. 113-129). Switzerland: Springer International.
- Ogden, J., Keay, S., Earl, G., Strutt, K., & Kay, S. (2009). Geophysical Prosepection at Portus: An Evaluation of an Integrated Approach to the Interpretation of Subsurface Archaeological Features. *Computer Applications to Archaeology*, (pp. 1-17). Williamsburg, VA.
- Stine, Linda F. and Roy S. Stine and Kristen S. Selikoff (2003). Multidisciplinary Landscape Research at Tannenbaum Historic Park, Guilford County, North Carolina. *North Carolina Archaeology* vol. 52:20-52.
- Stine, L., & Stine, R. (2013). Archaeological and Geophysical Research at Guilford Courthouse National Military Park (GUCO) Greensboro, North Carolina.
- Ward, Trawick and Joffre L. Coe (1976). *Archaeological Excavations at the Site of Guilford Courthouse*. Research Laboratories of Anthropology, University of North Carolina, Chapel Hill.
- Watters, M. S. (2012). *Geophysical and Laser Scan Surveys at the Longfellow House – Washington’s Headquarters National Historic Site*. NPS.
- White, D. A. (2013). LIDAR, Point Clouds, and Their Archaeological Applications. In M. J. Harrower, & D. C. Comer, *Mapping Archaeological Landscapes from Space* (pp. 175-197). New York: Springer.
- Yu-Min Lin, A., Novo, A., Weber, P. P., Morelli, G., Goodman, D., & Schulze, J. P. (2011). A Virtual Excavation: Combining 3D Immersive Virtual Reality and Geophysical Surveying. *Advances in Visual Computing: Lecture Notes in Computer Science (LNCS): 8th International Symposium* (pp. 229-238). Las Vegas: Springer.