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Recent Directions and Future Developments in Geographic Information Systems for Historical Archaeology

ABSTRACT

Geographic information systems (GIS) have become a core tool of archaeology by allowing the rapid comparison of complex datasets and supporting wholly new forms of analysis. This development is not surprising, since archaeology was one of the first disciplines to embrace the new technology as it became more commonplace in the 1980s. The past three decades have seen a proliferation of archaeological GIS studies, with the majority focusing on prehistoric contexts. While early examples of GIS for historical archaeology do exist, serious engagement with the technology did not emerge until the 2000s. The following article provides a much needed overview of the current state of archaeological GIS for historical archaeology. This includes a brief summary of previous and ongoing research to demonstrate the unique possibilities that emerge when historical archaeologists utilize GIS to its fullest potential. This overview groups the use of GIS into three familiar categories of inventory, geospatial analysis, and mapmaking. Building on this overview, the author examines emerging uses of GIS for historical archaeology. These new directions rely on historical archaeology's unique approach to studying the past, which relies upon the combination of artifacts, documents, and ethnohistory. These emerging forms of practice include counter-mapping, new forms of immersive 3-D GIS, and the possibilities of computer simulation. The article concludes with a frank discussion of the challenges that may hinder these potentials and the possibility for theory building between historical archaeology and other disciplines.

Introduction

In recent years a focus on the centrality of space has come to typify social-science and humanities research. This spatial turn increasingly views geographic information systems (GIS) as a vital component for broadening the understanding of the relationship of space, place, and culture (Soja 1989, 2009; Knowles 2000; Cope and Elwood 2009; Warf and Arias 2009; Gregory and Geddes 2014). Archaeology is unique amongst these disciplines because of its early adoption of GIS in the 1980s (Allen et al. 1990). Early uses focused on inventory, mapping artifact distributions, and the prediction of new locations. Numerous volumes and review articles since document a steady increase in the use of GIS by archaeologists (Lock and Stancic 1995; Aldenderfer and Maschner 1996; Kvamme 1999; Westcott and Brandon 2000; Wheatley and Gillings 2002; Ebert 2004; Conolly and Lake 2006; Evans and Daly 2006; Mehrer and Westcott 2006; Reid 2008; White and Surface-Evans 2012). The application of GIS remains one of the fastest growing areas of disciplinary specialization for archaeology, but the majority of this literature primarily focuses on prehistoric contexts. This article, modeled on similar reviews of archaeological GIS (Kvamme 1999; Ebert 2004), discusses the current state and future directions of GIS in relation to historical archaeology. In following authors like Kvamme (1999), I also group archaeological GIS into categories based on use. My three categories focus on the use of GIS for inventory and the management of archaeological resources, performing various forms of geospatial analysis, and mapmaking and data visualization. Historical archaeologists have been slower to integrate geospatial technologies into their research than colleagues working with prehistoric contexts. This is unfortunate, as a growing number of recent historical archaeological studies showcase innovative uses for GIS. I highlight these uses throughout the article with specific references drawn from a thorough review of the literature of the past two decades. These examples underscore how historical archaeology's inherent interdisciplinarity lends itself to the creative application of geospatial technologies.

The second half of the article is dedicated to discussing future potentials of GIS for historical archaeology. An additional three categories emerge, relating to participatory GIS and counter-mapping, the intersection of video games and 3-D GIS, and computer simulation. Participatory GIS and counter-mapping refer

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to inclusive forms of research that center public concerns alongside those of researchers, neatly intersecting recent trends in public archaeology. The intersection of video games and 3-D GIS allows users to experience the past in more interactive ways, while also delivering archaeological data in an increasingly intuitive format. Historical archaeologists have yet to experiment with computer simulation, but its growing availability via GIS software holds enormous potential for the analysis of the historical past. In addition to expanding the practice of historical archaeology, these future uses encourage grappling with pedagogical issues, while simultaneously supporting new avenues of theory-building in archaeology.

These potentials become more clear when GIS is thought of as a practice, rather than a simple tool. This difference is overlooked by many historical archaeologists, who consider the use of GIS synonymous with simple software (e.g., Excel). The use of GIS should be viewed in similar terms to the use of statistics. In many ways, the choice of specific software is irrelevant, and the important consideration is the underlying concepts of GIS and geospatial analysis. Conceptualizing GIS in this way supports a deeper engagement with the technology and, in turn, supports the rapid collection of field data, while cutting down on the time required to process and interpret that data.

Current Uses of GIS in Historical Archaeology

Categorizing the ways archaeologists make use of GIS is a complicated task, and previous scholars have proposed various classification systems. Aldenderfer's (1992) early scheme outlined three categories based on the ability of archaeologists to undertake specific forms of analysis. His first category focuses on analyses performed by archaeologists prior to the introduction of GIS. A common example is the creation of an artifact distribution map. The second examines analyses that are difficult to undertake without the aid of GIS. This includes predictive modeling, which can be conducted by hand, but rarely is because of its complexity (Kvamme 1999:172). Aldenderfer's third category refers to wholly new forms of analysis that are only possible with GIS. These include viewshed and cost surface analysis (see below). Aldenderfer (1996) later updated his classification system to focus on five primary uses: management of regional data, management of remotely sensed data (e.g., satellite imagery), regional environmental analysis examining the intersection of cultural and physical environmental characteristics, simulation of human behavior during prehistory, and predictive modeling. A more recent classification scheme by Fisher (1999) divides archaeological GIS on the basis of inventory, spatial analysis, and publication. Unlike Aldenderfer, Fisher's scheme recognizes the importance of map production. Kvamme's (1999) influential survey of archaeological GIS also recognizes the importance of mapmaking. He characterizes archaeological GIS along the following lines: management of regional databases of archaeological sites, within-site applications (mapmaking), and the management of remotely sensed data. He also explores the analytical capabilities of GIS and focuses on the predictive modeling of potential site locations; spatial allocation studies, which "attempt to associate sites or place with territories" (Kvamme 1999:174); intervisibility and viewshed analyses, as they relate to social and cognitive aspects of past human behavior; and the simulation of human behavior in response to various environmental changes (e.g., drought).

These examples mostly focus on the use of GIS for investigating prehistoric contexts, but how is it being used by historical archaeologists? A review of the literature shows that there are three categories of archaeological GIS as it relates to historical archaeology. The first examines inventory and geospatial database management, which remains the most common use of GIS for historical archaeology. The second category refers to various forms of geospatial analysis. This includes forms of analysis like predictive modeling, viewshed analysis, least-cost path analysis, and the comparison of various datasets. The final category involves mapmaking and data visualization. The following overview examines these categories of use and also alerts historical archaeologists to some of the exciting work currently taking place in regard to the use of GIS by their colleagues.

It is important to note that previous researchers have also discussed theoretical issues related to GIS. They comment on the ways archaeological GIS positions researchers between inductive and deductive approaches, the common location, theoretically speaking, for most archaeologists (Kvamme 1999:160–161). Similarly, Aldenderfer asserts that "GIS and associated technologies are theory-free, in that there is no necessary isomorphism between a particular data type or category and the use of GIS to solve or explore a problem" (Aldenderfer 1996:17). His comments respond to the charge that GIS privileges environmentally deterministic theories. These comments forecast similar thinking by recent theorists, including feminist geographers, who view GIS as a theory-free suite of tools useful for exploring a range of human activities (Cope and Elwood 2009). These authors also adopt the perspective that GIS is a practice and not simply a technique, highlighting how GIS combines with traditional scholarly practices to support new forms of analysis and theory building. I will revisit these ideas below.

Inventory and Geospatial Database Management

GIS is the most effective tool for the management of archaeological data, including the interpretation of remotely sensed data (Kvamme 1999:155; Kvamme and Ahler 2007). Geospatial databases of archaeological sites now exist for many U.S. states. For instance, the Florida Master Site File contains geospatial information on more than 30,000 archaeological sites. Most other states have completed or are in the process of creating similar statewide geospatial databases. It is important to note that the data contained within these databases often require verification, as many locations were digitized from hand drawings on historical maps. Still, statewide geospatial databases of archaeological sites remain important for managing and protecting sites from development, looting, and natural disasters. The use of GIS to inventory and manage archaeological data has important ramifications for the practice of fieldwork as well. Liebens's (2003) work at St. Michael's Cemetery in Pensacola, Florida, demonstrates how a thorough understanding of GIS in a project's planning stages benefits the overall project. A full appreciation of GIS can dramatically alter data collection in the field. The St. Michael Cemetery Project recorded detailed information and accurately mapped the location of 3,200 marked graves in a relatively short period of time. The field mapping took a three-person team 20 days to complete, and the creation of a GIS, hard-copy maps, and a web-based GIS (<http://sde3.gis.uwf.edu/smc/>) required another 8 days. A recent project by Tzortzopoulou-Gregory (2010) similarly demonstrates how a thorough understanding of GIS can aid field work. Tzortzopoulou-Gregory's project collected detailed information on 2,295 graves in 25 separate cemeteries in Greece. This database supports a sophisticated discussion regarding how long graves are tended by families. Similarly, Smith et al.'s (2003) work at a South Carolina Civil War battlefield demonstrates how the combination of fieldwork and GIS can illuminate the ways Confederates protected their transportation resources during the Civil War. Another benefit of using GIS to inventory archaeological data is the technology's ability to relate field data to other datasets, particularly environmental data. Wurst and Ridarsky's (2014:233) and Wurst and Mrozowski's (this issue) work in the Finger Lakes National Forest uses GIS to compare New Deal–era land classifications, recent USDA Soil Survey assessments, and archaeological surveys. This comparison highlights the inaccurate and hurried nature of New Deal–era land classification, in turn supporting the authors' investigation of historical myth and the subtle ways it influences the present.

The majority of current historical archaeology projects make use of GIS for inventory. This is particularly true for cultural resource management (CRM), where GIS has become a mainstay (Gray 1999) due, in large part, to the needs of various federal and state clients, who have invested considerable time in creating database management policies. This becomes a problem when archaeologists fail to keep pace with changes in geospatial database management. In addition to not understanding best practices for the management of geospatial data, many fail to integrate fully the database capabilities of surveying instruments (e.g., total stations) and GPS receivers into their fieldwork. These instruments are capable of digitally recording attribute data in the field, which substantially lowers the time required for data entry. While this approach requires additional time during a project's planning stage, the payoff in total data collected and time saved is considerable. The incorporation of this approach allowed a multinational team of 20 individuals to document the surface archaeology of two coal mining towns in Svalbard, Norway, during a two-week field season in 2004. This project successfully utilized two total stations, three Trimble GPS receivers, photography, and plan drawings to record features for nearly 80 structures at two separate town sites dating to the late 19th century (Figure 1). The benefit of a robust data-collection strategy incorporating the database capabilities of surveying equipment and GPS receivers was that fieldwork and data processing took less than one month. Team members from eight separate countries left the field with a complete GIS incorporating field data, environmental data, and georeferenced plan drawings.

The use of GIS for inventory and geospatial database management will continue to grow in historical archaeology. However, without properly formatted data and guidelines for its production and long-term management, the following uses of archaeological GIS become difficult or impossible. The simple truth is that many archaeologists do not accord this aspect of archaeological practice the respect it deserves and refuse to invest the time required to understand even basic data-management procedures. Instead, much of this work is left to specialists and, more commonly, graduate students, who are rarely involved with projects for their entirety. As a result, a discussion regarding best practices for geospatial database management within historical archaeology has yet to emerge—for an exception, see Tennant (2007)—students suffer from an incomplete understanding of the technology's potential, and projects are left to reinvent the proverbial wheel in regard to data collection, analysis, and presentation.

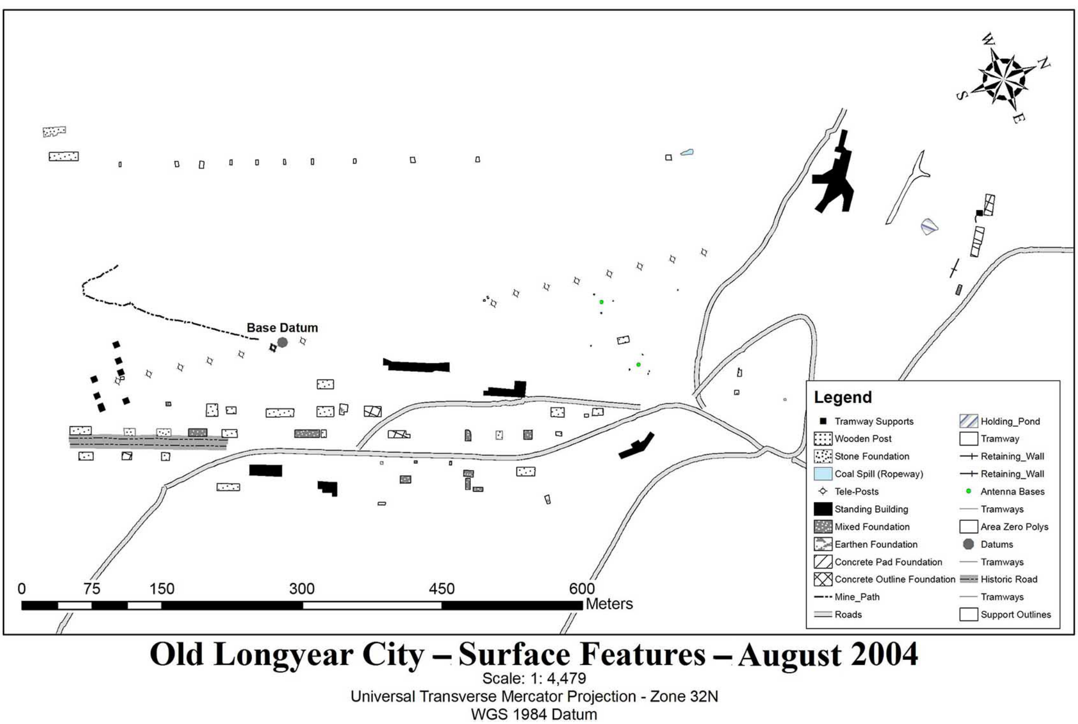


FIGURE 1. Map of the surface archaeology at Old Longyear City, Spitsbergen, Norway. (Illustration by author, 2005.)

Geospatial Analysis

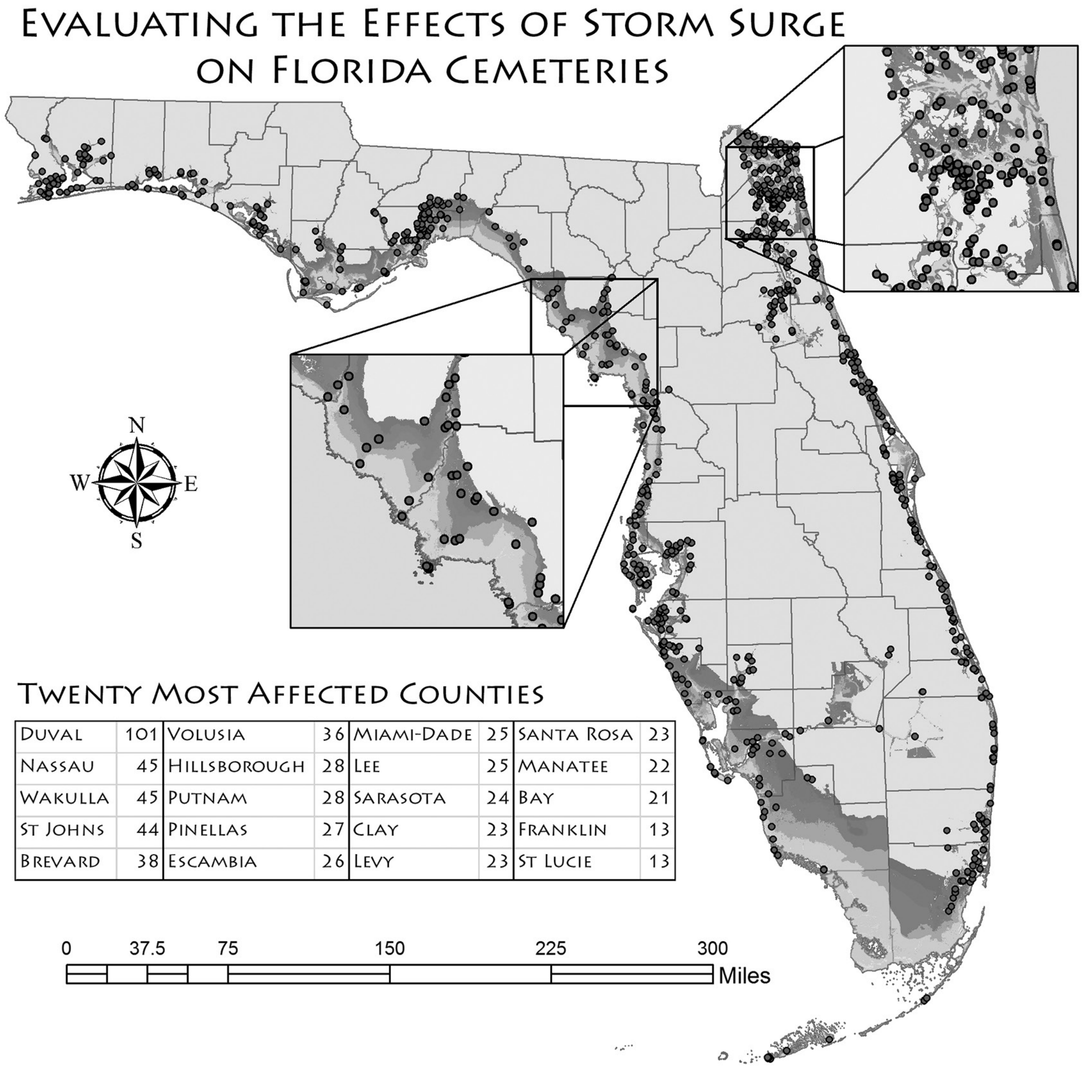
In theory, the versatility of GIS allows archaeologists to model and analyze data in countless ways (Delle et al. 2003:2). In practice, the geospatial analysis of archaeological data can be neatly grouped into three broad subcategories: locational modeling, cost surface analysis, and visibility analysis. Locational modeling combines cultural and environmental data for predictive modeling and to calculate site catchments in order to better understand territoriality. Cost surface analysis, which many consider as a type of locational analysis (Kvamme 1999:174–176), is a rapidly expanding form of geospatial analysis that determines the cost of travel across a landscape. I treat it as a separate category, due to the proliferation of such studies in recent years (White and Surface-Evans 2012). Finally, visibility analysis involves the use of elevation data to determine the visible area of a single point or multiple points on the landscape.

These types of analysis are vital tools for protecting sites from climate change, including the effects of sea-level rise (SLR) and worsening storm-surge levels. Westley et al. (2011) undertook this form of analysis for sites that are threatened by coastal erosion, such as L'Anse aux Meadows in Newfoundland, Canada. That project compares desk-based GIS modeling with field surveys of endangered coastal sites, while incorporating region-specific models of SLR derived from local digital elevation models (DEM) and soil maps. The resulting vulnerability index demonstrates that desk-based modeling combined with targeted field survey produces an analysis of study areas more comprehensive than limited spot checks or desk-based analysis alone. A similar project examining the effects of changing urban land-use patterns on archaeological resources in northeast Florida demonstrates the importance of moving between locational analysis and fieldwork (Sassaman et al. 2003). These studies are important examples regarding the ability of GIS to support the management and protection of archaeological sites by combining inventory work with geospatial analysis.

Locational analysis provides a powerful method for historical archaeologists to engage the public on topics related to heritage and policy. This typically intersects with the importance of mapmaking and data visualization as well. Figure 2 visualizes the results of an analysis of the potential effects of storm surge on cemeteries in Florida. The storm-surge estimations are based on the National Oceanic and Atmospheric Administration's Sea, Land, and Overland Surges from Hurricanes (SLOSH) model. The SLOSH model was developed to estimate storm-surge heights based on atmospheric pressure, size of the storm, and local landforms. Preliminary results from this analysis suggest that more than 800 cemeteries, approximately one-quarter of all cemeteries in the state, are currently at risk from a storm surge. This and similar figures are being used by researchers to raise awareness of the vulnerability of historical resources along the state's coastlines.

Another common form of locational analysis focuses on settlement patterns. While the investigation of prehistoric settlement patterns remains commonplace, similar analyses by historical archaeologists are still rare. An early example by I. Williams et al. (1990) examines the integration of documentary evidence within a GIS to explore the settlement history of Fort Hood, Texas. As part of the U.S. Army's management of this location, 90% of the 390 sq. mi. has been inventoried, resulting in a database covering 2,300 prehistoric and historical sites. Drawing on this data, the authors compare the location of historical settlements during the early 20th century with more recent USGS soil data. They found that sites are "unevenly distributed with respect to the potential yields" of cotton and oat crops (I. Williams et al. 1990:252). Tapia's (2005) more recent analysis is another form of settlement analysis and examines how European settlement influenced the movements of Ranquel Indians in Argentina during the 18th and 19th centuries. Her analysis of 168 settlements combines archaeological evidence, surviving toponyms, and environmental data to examine how indigenous groups responded to the often violent colonial practices of European settlers.

The most common type of locational analysis for archaeology is predictive modeling (Westcott and Brandon 2000; Mehrer and Westcott 2006). Predictive modeling is central to CRM



Duval	101	Volusia	36	Miami-Dade	25	Santa Rosa	23
Nassau	45	Hillsborough	28	Lee	25	Manatee	22
Wakulla	45	Putnam	28	Sarasota	24	Bay	21
St Johns	44	Pinellas	27	Clay	23	Franklin	13
Brevard	38	Escambia	26	Levy	23	St Lucie	13

FIGURE 2. Evaluating effects of storm surge on Florida cemeteries. (Illustration by author, 2015.)

because it helps to reduce costs associated with archaeological survey (Gray 1999:61; Kvamme 1999:174). The results of a predictive model typically identify areas with low, medium, and high probabilities of new sites. Field crews then undertake systematic field survey in high and moderate areas, and may also undertake random surveys in low areas to test the predictive model's accuracy. Predictive modeling is not without risks. Once a predictive model is established for a region, it quickly becomes entrenched, and refinement is rare. In addition, predictive models often indicate what experienced archaeologists already know about an area. Many archaeologists also feel that predictive models rely on a form of environmental determinism. One way to answer these critiques is to introduce forms of analysis that reproduce past forms of cognition and experience, e.g., Jones (2006). For instance, Gallagher and Josephs (2008) drew on light detection and ranging (LiDAR) data to aid in locating new sites in Isle Royale National Park in the Upper Peninsula of Michigan. These authors used LiDAR's highly accurate and precise elevation data to identify anthropogenic features associated with historical mining. Their methodology includes field survey of features in order to refine their approach to predictive modeling for historical archaeology.

Other forms of predictive modeling become available with robust documentary data. The creation of a document-driven predictive model is at the center of research into Rosewood, Florida (González-Tennant 2011, 2013). The 1923 Rosewood Race Riot resulted in the violent displacement of the area's black population and the systematic burning of every black-owned structure in the town. While the majority of Rosewood remains undeveloped, nearly a century of soil deposition, private construction, and light farming obscure subsurface remains. Systematic survey is hampered by the town's relatively large footprint (more than 2 sq. mi.), sparse historical population, and current private ownership. As such, the organization and analysis of property deeds represent the primary method for predicting the location of historical houses.

Unlike other locations with a rich documentary record consisting of property maps, such as studies in the Finger Lakes region of New York (Heaton 2003), no maps or city directories of Rosewood's rural location survive. Addressing such deficits requires a unique approach to the documentary record. In Rosewood this consists exclusively of metes-and-bounds descriptions associated with property deeds. These descriptions document straight paths measured along a compass bearing that begins and ends at specific points, creating a closed polygon or area representing a property's boundary. Metes-and-bounds descriptions are often used on single properties by historical archaeologists when tracing property ownership. This is a relatively straightforward process, allowing historical archaeologists to trace quickly ownership of single properties through time. Such data are often woven into the historical setting or background research sections of books and articles, e.g., Yentsch (1994). Others have reconstructed metes-and-bounds descriptions to examine the colonial relationships between elites and indigenous communities (Sampeck 2014). In Rosewood, the methodology for reconstructing property ownership involves the following steps: (1) Identify the appropriate historical property records, (2) translate the metes-and-bounds description into a GIS file, (3) identify the owner in the census, (4) add census data to the GIS record, and (5) overlay this information on other forms of data. These additional forms of data include aerial photographs from the 1940s, to help visualize the exact locations of boundaries and structures. These steps are repeated hundreds of times for a 50-year period between 1870 and 1930. The resulting Rosewood historical properties GIS (HP-GIS) represents the largest systematic use of property records undertaken as part of an historical archaeology project. The resulting GIS (Figure 3) allows researchers to predict the locations of structures within the town's historical boundaries accurately. Limited archaeological testing has verified the accuracy of the GIS at numerous locations.

Cost Surface Analysis

Cost surface analysis (CSA) calculates the energy required to move through an environment and, typically, involves the assignment of travel costs to each cell in an elevation dataset. These weights make use of slope to model mathematically the cost of travel across a landscape. Archaeologists apply least-cost analysis (LCA) to a variety of archaeological issues, locations, and time periods (Hunt 1992; Kelly 1992; Anderson and Gillam 2000; White and Surface-Evans 2012). The primary use of LCA focuses on the creation of least-cost paths (LCP) to represent the least costly and, thus, most likely routes from one point to another across a landscape. Simple forms of LCP analysis rely solely on slope, resulting in a form of *isotropic* analysis (Surface-Evans and White 2012:3). These forms of analysis are sufficient to model the least-costly path. When research calls for calculating specific measurements, such as time or caloric cost, then an *anisotropic* analysis is required. These forms of analysis are accomplished in a GIS by calculating different values for each cell based on the direction of travel. Several recent studies in White and Surface-Evan's (2012) volume adopt this more complex form of LCA to examine a range of prehistoric contexts. Creating an anisotropic analysis is useful because routes may change significantly depending on the origin and destination.

A handful of interesting studies demonstrate LCA's potential for contact period and historical archaeology. A thought-provoking

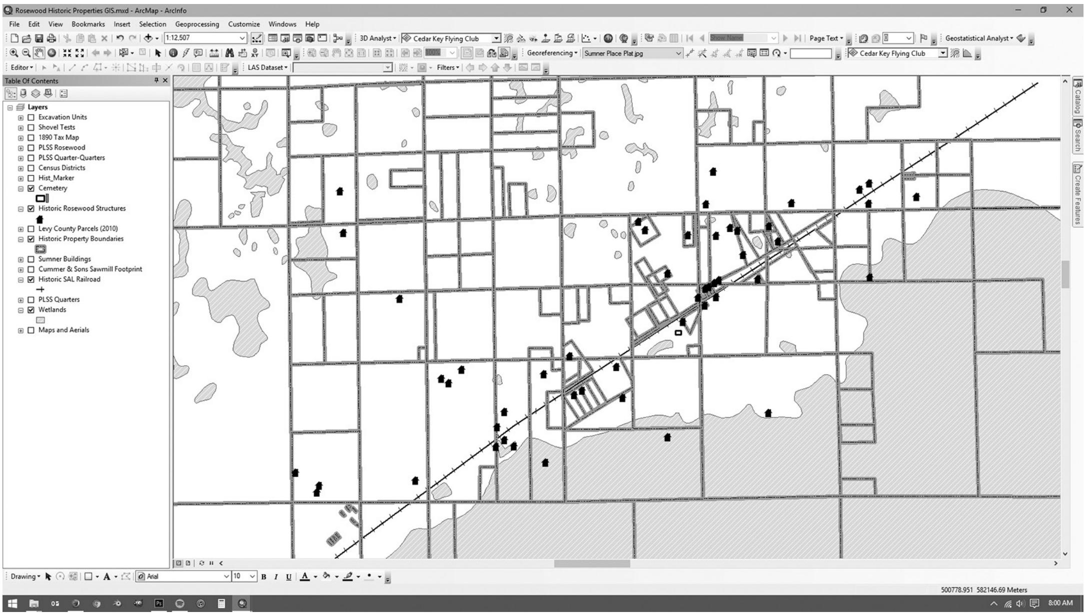


FIGURE 3. Opening screen of the Rosewood historic properties GIS. (Illustration by author, 2011.)

article by Whitley and Hicks (2003) draws on LCA to examine the antiquity of historically recorded routes in Georgia. The methodology examines the locations of known archaeological sites, dating between the Archaic and early historical periods, in relation to travel corridors. This begins with the digitization of five historical trails crossing the study region. Then, a series of primary and secondary LCPs are calculated using a hiking function (Tobler 1993) as a form of anisotropic analysis to represent the potential travel corridors within their study area better. Unsurprisingly, the strongest correlations exist between Mississippian sites and the historical routes, although one or two routes appear to have been in use for millennia. Another example of LCA is Seifried's (2014) analysis of population change between Ottoman period settlements in Mani, Greece. Her analysis combines LCA and viewshed analysis (see below) to investigate the relationships among historical communities during a politically volatile period. Seifried's analysis supports a new reading of the ways locals responded to external threats. Instead of retreating to more mountainous areas, as might be expected, her analysis suggests a mix of responses were more common than any single tactic.

Battlefield and conflict archaeology can also use LCA. This type of analysis can assist in locating camps or explaining troop movement. LCA analysis is helping to explain troop movements during the 1706 French invasion of Nevis, British West Indies. The French choice to land troops on the island's southeast coast followed an earlier, unsuccessful attempt to invade the capital. After landing, troops made their way to the western side of the island and took possession of Charlestown, Nevis's capital city. The nearby Fort Charles, which is positioned to protect Charlestown's harbor, was unable to prevent the French troops from entering the town by land. Figure 4 illustrates the most likely route taken by the French, based on LCP analysis. This figure also shows contour lines related to both isotropic and anisotropic cost times based on distance. The predicted route bypasses Fort Charles. This route is also located to the south of the Saddle Hill fortifications, which were specifically constructed in response to the invasion. The LCP analysis suggests one reason these fortifications were positioned so far inland, too far to be of use in defending the coast. The invasion had a lasting impact, and LCP analysis frames this in terms of the island's archaeological resources (González-Tennant 2014).

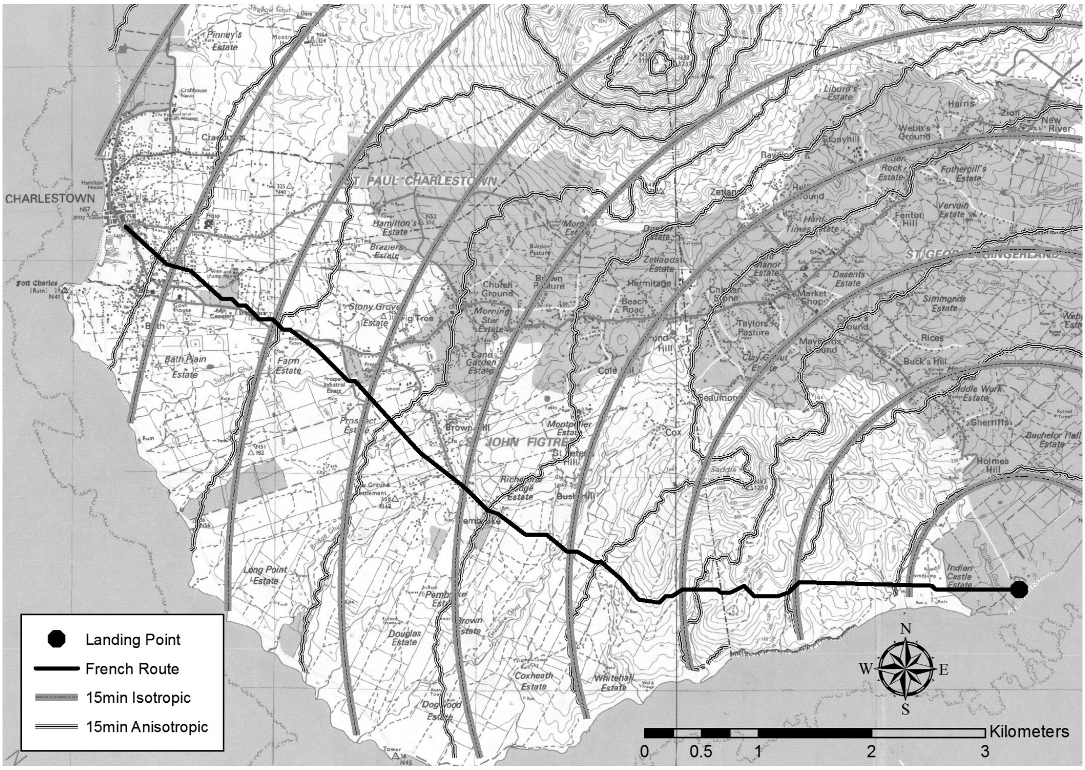


FIGURE 4. Least-cost pathway (LCP) analysis of the 1706 French invasion of Nevis. (Illustration by author, 2015.)

Visibility Analysis

Visibility analysis provides archaeologists with a way to model cognitive and experiential aspects of past landscapes (Kvamme 1999:177). Viewsheds represent the most common form of visibility analysis, mathematically modelling the visible space from an observation point or series of points. Viewsheds provide a dual perspective, in that they also define the area from which the defined point or points are visible. This form of analysis has been drawn upon by historical archaeologists to investigate surveillance and social control on plantation sites (Delle 1998, 1999; Whitley 2002). Liebens's (2003) viewshed analysis of St. Michael's Cemetery in Pensacola, Florida, identified areas that would be suitable for the construction of a new building. These locations were not visible from main entrances and, therefore, would not interfere with the cemetery's existing landscape. Jones's (2006) analysis of the role visibility played in settlement choice among the Onondaga Iroquois between A.D. 1500 and 1700 represents a more sophisticated application of this analysis. Whereas other studies might focus on environmental conditions found at sites to interpret their locations, Jones highlights the importance of defensibility, representing a novel use of viewshed analysis. Similarly, work with gold mining sites in the Otago Region of New Zealand utilized viewsheds to model soundscapes at an historical mining town (González-Tennant 2009:31–34). This analysis uses viewsheds to calculate soundscapes related to historical gold mining (e.g., stamping batteries) and explores its effect on settlement choice at Nenthorn, a boom-and-bust town built on speculation during the 1890s.

Archaeologists who undertake viewshed analysis often discuss the importance of selecting appropriate data (Conolly and Lake 2006:103). This primarily relates to the type of elevation data selected for the analysis. Figure 5 shows the results of using two different kinds of elevation data for modeling viewsheds at Fort Charles, Nevis. Figure 5*a* employs 20 ft. contour data digitized from a British Ordinance Survey map created in the 1980s. The process of creating an elevation surface from contour data involves the creation of an intermediary dataset referred to as a triangulated irregular network (TIN). Contour data is stored in a vector data model and then converted into a TIN, which is then converted into a DEM raster (Conolly and Lake 2006:103–104). The effect of these translations is that the resulting viewshed may contain banding (sometimes referred to as "tiger stripes") that represents an artifact from the imperfect conversion from vector contours to DEM. Figure 5*b* shows a viewshed for the same area, utilizing USGS 30 m DEM data. This dataset produces a smoother and more accurate viewshed. The increasing availability of DEM data around the world makes this form of analysis more accessible today than ever before. Data warehouses, such as the USGS Global Data Explorer, <http://gdex.cr.usgs.gov/gdex/>, provide 30 m DEM data for the majority of the planet. In addition, the cognitive aspects of viewsheds, as well as their versatility, allow historical archaeologists to model experiential elements of past landscapes. Projects seeking to investigate landscape and perception will usually benefit from incorporating visibility analysis.

Mapmaking and Data Visualization

The final category of archaeological GIS I will discuss is mapmaking and data visualization. While others may downplay these functions, their importance for archaeology is clearly obvious (Aldenderfer 1992; Kvamme 1999:161–162). The creation of maps locating archaeological features in relation to one another and the surrounding environment supports a deeper engagement with the data. The degree to which features and objects cluster can be verified through various spatial autocorrelation tests. Even without statistical verification, distribution mapping is often useful to discover patterns. Many archaeologists increasingly consider the mapping and visualization of archaeological data to be a form of data visualization (Llobera 2011). Archaeologists who embrace this aspect of GIS are able to communicate complex patterns in accessible ways. Lazrus (2014) utilized distribution maps to discuss the role of accessibility in the remote municipality of Bova, in Calabria, Italy. Her analysis combines historical documents with field survey to discuss how that area remained under the strict control of local church authorities well into the early 20th century. The incorporation and display of historical evidence represents one of the fastest growing areas of historical archaeological GIS. Armstrong et al. (2009) utilized mapmaking to investigate issues of pre-Emancipation freedom and land ownership of Afro-Caribbean communities in the Danish West Indies, representing a continuation of the senior author's earlier research (Armstrong 2003). Their study combined historical maps, tax records, and field survey to document dynamic cultural and economic developments in the late 18th century. This approach supports a revaluation of the scope of slavery, freedom, and social interactions in comparison to other islands. In addition to supplying a model for similar analyses across the Caribbean region, their project represents an important step away from the common practice of analyzing plantations in isolation.

Many GIS software packages can display data in 3-D, adding an additional dimension to interpretation. Stine (2000) uses GIS's 3-D capabilities to examine artifact distributions at the Reed Gold Mine blacksmith shop near Georgeville, North Carolina, to successfully locate the shop's forge. Others utilize the 3-D capabilities of GIS to undertake new forms of landscape analysis. The growing availability of LiDAR is motivating historical archaeologists to incorporate this data into their research. Harmon et al. (2006) used LiDAR at Wye Hall and Tulip Hill plantations in the Chesapeake to assess the usefulness of two different LiDAR datasets, one at a 2 m resolution and the other at 1 m. While a finer resolution is often preferred, the study demonstrates how either dataset is adequate. These forms of visualization represent the continuation of earlier forms of archaeological mapmaking, including the creation of site plans and artifact distribution maps.

Artifact distribution maps are perhaps the most common form of archaeological

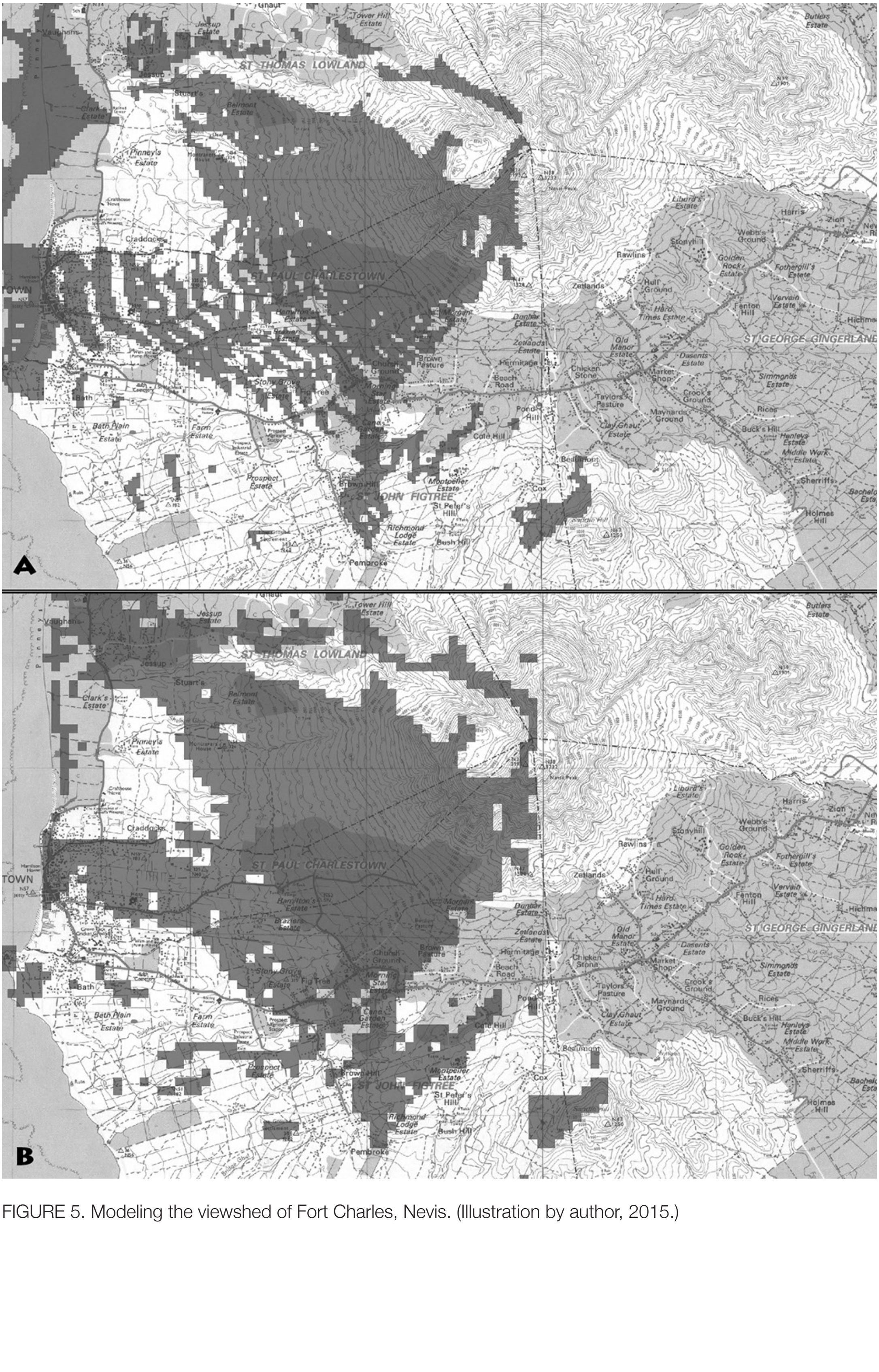


FIGURE 5. Modeling the viewshed of Fort Charles, Nevis. (Illustration by author, 2015.)

visualization. Although archaeologists tend to favor isolines (colloquially referred to by many as contour lines), this preference is partly the result of technology influencing practice; specifically, the ability of early computer-assisted drawing (CAD) software to produce isolines. GIS allow for additional forms of distributional mapping. Figure 6 shows four techniques for mapping the same artifact density data from the site of En Bas Saline, Haiti; for information on this site please see Deagan (2004). Figure 6*a* uses the more familiar isolines to connect areas of similar artifact densities. Figure 6*b* is a choropleth map of the same data. Choropleth maps are thematic maps that use shaded or patterned colors to represent data values. These maps typically represent values associated with polygons. As such, a 2 m grid was generated to enclose the points of the En Bas Saline shovel tests. The artifact counts at each point are then summed and added to each polygon. These values can then be represented as either choropleth or dot-density maps

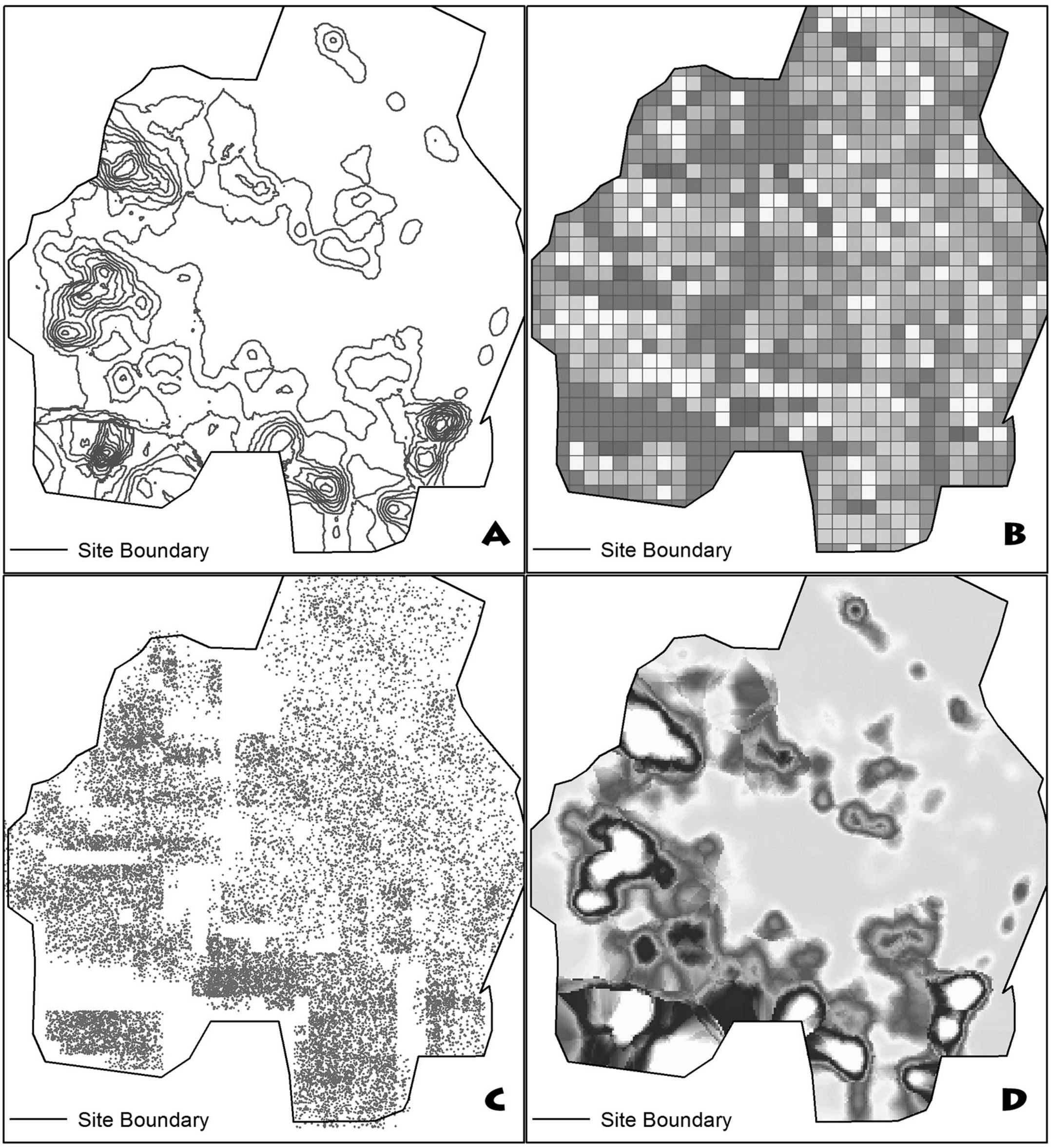


FIGURE 6. Mapping artifact densities at En Bas Saline, Haiti. (Illustration by author, 2015.)

(Figure 6*c*). A final method for representing artifact counts involves the creation of a 3-D surface. Figure 6*d* represents the same data as a continuous surface, the height values of which represent artifact counts for each cell. This raster was created using the Kriging tool, which represents a form of interpolation using geostatistics and is generally accepted to be the preferred method for creating elevation surfaces from artifact counts (Conolly and Lake 2006:97–100). Historical archaeologists looking to represent artifact densities should feel encouraged to experiment with these different tools, as each one conveys data in a slightly different way.

The use of GIS by historical archaeologists continues to expand, as evidenced by the overview above. Grouping uses into three categories of inventory, geospatial analysis, and visualization demonstrates that we historical archaeologists are making use of the technology in ways similar to our prehistoric colleagues. We will continue to develop unique approaches to archaeological GIS. The above examples also demonstrate that our discipline is beginning to embrace geospatial technologies in ways that make it our own. The following section goes into greater detail regarding three potential, yet rarely implemented, forms of GIS for historical archaeology: participatory GIS, video games and 3-D GIS, and simulation.

Future Directions of GIS in Historical Archaeology

The previous overview showcases many of the ways we historical archaeologists are making use of GIS. These include common uses, such as inventory, as well as a growing group of researchers who are exploring more complex uses of the technology. Whereas prehistoric archaeologists will continue to refine their use of GIS along the above lines, our combination of artifacts, documents, and ethnohistory will allow us to expand the uses of GIS beyond those previously discussed. This section outlines three possible directions. The first is participatory GIS and counter-mapping, which intersect both inventory and visualization while centering public interests and knowledge. The second combines GIS and video games to explore archaeological data to support a deeper engagement between archaeologists and the public by utilizing increasingly intuitive digital environments. The final direction involves the use of computer simulation, which offers intriguing possibilities for the investigation of the historical past. My decision to order these three potentials is deliberate and can be conceived in ways similar to Aldenderfer's (1992) early scheme on the basis of how regularly archaeologists make use of these functions. Participatory GIS is a growing practice by historical archaeologists, whereas the use of digital technologies to represent geospatial information has rarely been undertaken, and the exploration of simulation for the historical period is explored even less.

Participatory GIS and Counter-Mapping

At the core of participatory GIS (P-GIS) is the "the empowerment of communities through the facilitation of greater community input and access to geospatial data and technologies" (Rouse et al. 2007:153). P-GIS began as a movement in the natural sciences to include local and indigenous perspectives alongside scientific mapping of natural resources. The value of including local perspectives improves data gathering by reducing the time required to identify and map resources. A closely related concept, counter-mapping is defined as the use of cartography by a group "or ethnic minority to assemble data, generate maps and other graphic representations, and disseminate these materials for the purpose of better understanding" a wide variety of topics as expressed spatially (Maantay and Ziegler 2006:275). This concept is closely related to P-GIS in that it centers local knowledge in visual representations of the world. Counter-mapping allows researchers and concerned citizens to posit alternative interpretations alongside one another. These are counter-hegemonic practices in that they highlight the social tension that develops between the present (dominant) ideologies as they usurp/replace previous (residual) ideologies, as well as contending with new, often marginal (emergent) ideologies (R. Williams 1977). A primary location for the interplay between these various forms of ideology is in the naming and un-naming of places, events, and experiences. Mapmaking is integral to this process (Sampeck 2014).

Purser (2012) frames her ongoing research in Levuka, Fiji, as a form of P-GIS. Her research engages the political nature of historical knowledge production. This project highlights the way GIS technology recasts "earlier archaeological debates about authority, representation, and agency in community-based research" (Purser 2012:497). Purser utilizes the flexibility of GIS as a powerful tool for incorporating archaeological, ethnohistorical, and geospatial data. The visualization of overlapping and sometimes competing narratives has an important role to play in regard to managing resources, land claims, and the creation of a multivocal past. Purser's work reveals the ability of GIS to address deeply ethical aspects of archaeological practice. Similarly, Myers (2010) explores the ethics of remotely sensed data in regard to Camp Delta, Guantánamo Bay, Cuba. His research uses ArcGIS to analyze aerial imagery from Google Earth and explore the rapid expansion of Camp Delta during the early 2000s. This research found that such analysis "both confirms and extends, and has the potential to contradict, what is officially stated and displayed about places like Camp Delta in other sources" (Myers 2010:464). Myers work is also an important example of how we historical archaeologists can intersect emerging concerns in the archaeology of the recent and contemporary past (Buchli and Lucas 2001). Historical archaeology's ongoing commitment to connecting the past with the present should also motivate us to visualize the continuation of social inequalities through time. For instance, mapping the unfair treatment of minority individuals by the police in U.S. cities or the ongoing segregation of American society represent important forms of truth telling in which GIS users can participate. The data utilized for these visualizations demonstrate how these practices are not restricted to any single region, but are, in fact, society-wide practices. Figure 7 visualizes the total number of police stops in New York City during 2012 as part of the city's Stop-and-Frisk Program. Of the more than 528,000 stops conducted during that year alone, 51% involved African Americans, 31% involved Hispanic and Latino individuals, and only 8% involved people of European ancestry. Inequalities like this provide a stark reminder of the work that remains in America regarding racial difference and social justice, and intersect our growing interest in connecting our work with modern issues.

P-GIS and counter-mapping will continue to grow as historical archaeologists explore collaborative approaches to archaeology (Harrison 2011). These approaches represent powerful methods for engaging modern communities, a necessity when undertaking research that makes the past relevant for the present. In addition to expanding the body of information available to historical archaeologists, P-GIS and counter-mapping intersect the growing focus on collaborative archaeology (Colwell-Chanthaphonh and Ferguson 2007; Castañeda and Matthews 2008; Silliman 2008). This approach closely mirrors community-based participatory research (Whyte 1991; Atalay 2012) and is seen as an alternative to traditional academic practices that reduce the public's role to that of passive consumer. The collaborative aspect of counter-mapping will continue to grow as historical archaeologists search for new methods to connect their research to the present in meaningful and socially transformative ways.

Immersive Qualitative GIS (IQ-GIS)

The second area of growth for historical archaeology centers on the combination of GIS and video game technologies. The combination of GIS and 3-D technologies, often referred to as 3-D GIS, continues to receive limited attention from archaeologists (Kvamme 1999:165). Recent advances in computing power, high-speed Internet access, and software to create video games (referred to as game engines) provide a unique method for disseminating archaeological data. The use of game engines to visualize these data provides an immersive way to explore spatial and nonspatial elements of archaeological data. One result of the growing popularity of video games is that exploration and movement within virtual environments feels

FIGURE 7. Visualizing New York City's Stop-and-Frisk Program. (Illustration by author, 2015.)

increasingly intuitive to a growing segment of the population. Only a handful of historical archaeology projects currently utilize 3-D and video game technologies. Research into the history of Rosewood, Florida, is one example (González-Tennant 2011, 2012, 2013). The University of South Florida's Alliance for Integrated Spatial Technologies (<http://aist.usf.edu/>) and the Virtual Curation Laboratory at Virginia Commonwealth University (<https://vcuarchaeology3d.wordpress.com/>) both use 3-D scanning to document historical sites and archaeological materials. Additional examples of projects utilizing game engines to interpret archaeological contexts include the Virtual Williamsburg Project (<http://research.history.org/vw1776/about/>) and the Digital Montpelier Project (<http://www.digitalmontpelier.org/>). These projects are important ones, as they demonstrate the power of this technology to interpret sites at different points in the past.

The combination of these technologies can accomplish more than the virtual reconstruction of archaeological sites. The immersive and interactive qualities of game engines provide a method for sharing both quantitative and qualitative data with other researchers and the public. The Virtual Rosewood, Virtual Williamsburg, and Digital Montpelier projects make use of the immersive aspects of game engines, but have not fully engaged with the ability of this technology to transpose various datasets and interpretations alongside one another in real time. A digital experience that fully engages this aspect of the technology will result in what I call an immersive qualitative GIS (IQ-GIS), allowing users to explore simultaneously a wide range of archaeological data and interpretations. This represents an emerging practice that is well suited to engaging a broader segment of the public. The combination of these technologies is currently being applied as part of ongoing work at the site of Fort Charles, Nevis. The development of an IQ-GIS for this site is part of a multiyear project examining three centuries of cultural change at one of the Caribbean's earliest and longest-occupied British forts. Users of the project's IQ-GIS are able to interact with various datasets through a series of clickable menus and objects to explore various interpretations of the site (Figure 8), which also unmasks the interpretive decisions made by archaeologists. The Fort Charles IQ-GIS is being designed in cooperation with heritage workers and various stakeholder groups in Nevis and is expected to be part of a museum exhibit at one of Nevis's public museums.

We historical archaeologists are uniquely situated to create IQ-GIS (or whatever researchers ultimately decide to term their combined use of these technologies). Our discipline's reliance on multiple datasets should similarly encourage us to explore multiple ways of representing those data. Doing so will allow us to occupy a unique position in leading transdisciplinary research, but only if we truly embrace and collaboratively explore the intersection of these technologies. This type of work is particularly well positioned to intersect emerging trends in other disciplines (e.g., digital humanities) and act as an important bridge between researchers and the public. Historical archaeology's engagement with GIS provides us the opportunity to engage other researchers as collaborators and even leaders, a point I return to in the discussion section below.

Computer Simulation in Historical Archaeology

The previous two future areas of growth for GIS in historical archaeology are already being actively explored. There is very little work taking place in regard to the third area of growth, the use of computer simulation. Computer simulations of prehistoric contexts and peoples has a long history in archaeology (Doran and Hodson 1975; Bell 1987; Aldenderfer 1991; Mithen 1994; Kohler 2000; McGlade 2005; Costopoulos 2009). Computer simulation refers to models that "represent some facet of the real world as a set of variables linked by mathematical or logical conditions and which are studied by repeatedly replacing those variables with numbers until some specified conditions are met" (Lake 2014:259). In his recent article, Lake outlines four periods of archaeological simulation, beginning with an initial pioneer phase in the 1960s, moving through evolutionary-based studies in the 1980s to a third phase examining agent-based modeling in the 1990s. Agent-based modeling involves the creation of rules and instructions that are given to virtual agents, who then interact with one another and/or the environment. The simulation often lasts multiple generations and is repeated with variations on the initial instructions. Agent-based modeling is particularly amenable to agency and practice theory because of the ability to alter the behavior of individual actors. Lake's fourth "expansion phase" remains ongoing since 2001 and represents a rapid growth in the diversity of approaches to archaeological simulation.

Increasingly, archaeological simulation makes use of GIS software, and, while rarely undertaken by historical archaeologists, computer simulations of historical periods do occur. A recent study explores simulation of historical battlefields to simulate military tactics during the 18th-century War of the Spanish Succession (Rubio-Campillio et al. 2012, 2013). These projects seek to produce a deeper understanding of taphonomic processes, as well as motivating researchers to revisit their fieldwork methodologies. Similar research includes studies simulating the spread of settlers in the western United States (Campos et al. 2006). Any analysis that suggests specific behaviors on the part of historical actors or communities is capable of supplying the rules for simulation studies. One likely reason that historical archaeologists have not explored computer simulation is the programming knowledge required to run such experiments,

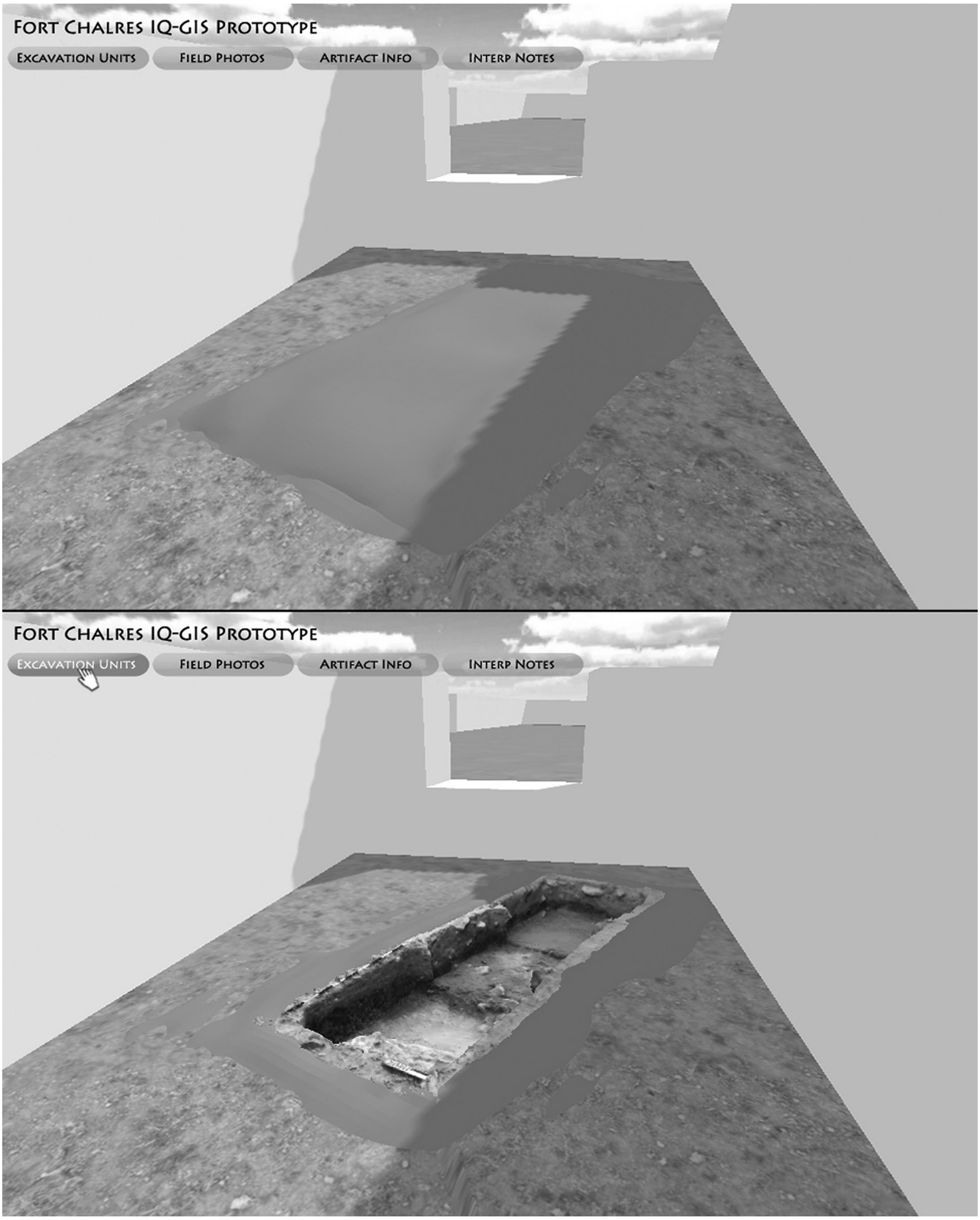


FIGURE 8. Fort Charles Archaeological Project IQ-GIS prototype. (Illustration by author, 2015.)

but this is changing. A number of toolkits are now available that support the creation of simulation studies through the use of familiar GIS software. A particularly accessible example is the recently released Agent Analyst extension for ArcGIS. This software is freely available and includes a manual and exercise data (<http://resources.arcgis.com/en/help/agent-analyst/>). Similarly, a free package for GRASS GIS is the MAGICAL toolkit, <http://www.ucl.ac.uk/~tcrnmar/simulation/magical/magical.html>.

A number of potential simulation projects exist for historical archaeology. The ability to model pedestrian movement using least-cost path analysis has received attention from prehistoric archaeologists (White and Barber 2012). The application of this approach to historical sites will intersect more theoretical work concerning the role of surveillance and land use on plantation sites (Armstrong 1985; Delle 1998, 1999; Epperson 1999; Singleton 2001). Agents in these simulations may receive instructions regarding movement and activities based on viewshed analysis. Such rules will result in virtual agents avoiding areas of higher visibility. The resulting analysis will shed light on the frequency and duration of time spent in specific locations, in turn identifying areas that served as intermediary spaces between public and private places. Another intriguing aspect of simulation is the ability to utilize points and polygons as actors. This allows for individuals, households, or entire communities to act as agents in a simulation. Historical archaeologists can simulate the mix of characteristics associated with practices such as neighboring (Adams 1976:104). Such a project will involve the assignment of rules regarding preferences for interacting with neighbors who share similar backgrounds or perspectives (e.g., national background, religious affiliation, minority status). It will also require a series of adjustments to the rules agents follow during subsequent iterations of the simulation. These studies will also require a mix of archaeological, documentary, and ethnohistorical evidence to identify similarities that affect decision making. Once such a model matches the archaeological record, it can serve a range of functions for other studies. The model may support additional theory building about the role identity plays in forming the archaeological record or act as a toolkit to test further case studies. Those simulations that model choice on ethnic or racial backgrounds will force historical archaeologists to formalize the rules governing identity, inequality, and social structure (e.g., structural racism).

As with IQ-GIS, computer simulation in historical archaeology represents a new field of study. It also suggests a novel method for bridging the academic/professional divide amongst archaeologists. The development of predictive models is an earlier example of GIS practice that brought academic and professional archaeologists into conversation. The model building required for simulation studies may serve a similar purpose. Simulation projects will require case studies drawn from both academic and contract work. The ability to save and share models and then apply them to new contexts and periods can support increased collaboration across this (fictitious) barrier. Realizing such possibilities will require new pedagogical techniques that also address ethical issues regarding subsequent generations of historical archaeologists vis-à-vis an unstable job market. Providing educational opportunities for students interested in historical archaeology is perhaps the single greatest challenge to fully realizing the technology's potential for this discipline.

Discussion

The use of GIS is now a core aspect of historical archaeology, but work remains to fully realize the technology's potential for the discipline. The growing exploration of more complex forms of geospatial analysis by historical archaeologists suggests that the short-term future of GIS for historical archaeology will partly mirror the growth of GIS for prehistoric archaeology in the 1990s. The majority of historical archaeologists will continue to use the technology for common tasks (e.g., inventory, mapmaking). Fortunately, historical archaeology's exploration of GIS will not face the same challenges that existed 20 years ago. In addition to lower computing costs and better training resources, archaeologists are no longer burdened by simplistic critiques of GIS as environmentally deterministic. This, coupled with the increasingly routine inclusion of qualitative data into historical archaeological research opens new vistas of experimentation, methodological development, and theory building.

The intersection of GIS and 3-D/gaming technology (what I refer to as IQ-GIS) presents one possibility for transdisciplinary theory building. In addition to the immersive and interactive qualities of game engines, IQ-GIS draws theoretical inspiration from recent discussions of qualitative GIS (QualGIS). QualGIS is rooted in a "hybrid understanding of GIS as technology, methodology, and situated social practice" (Elwood and Cope 2009:3). For Elwood and Cope, considering the inclusion of qualitative data alongside quantitative data within GIS involves three interrelated ideas. First, QualGIS treats knowledge as partial and situated, echoing feminist scholars of science (Haraway 1988). Users of GIS are encouraged to understand that epistemology need not determine methodology; data are open to multiple interpretive frameworks. This echoes sentiments long held by scholars following early explorations of postmodernism for archaeology (Knapp 1996). Second, QualGIS acknowledges the inherently political nature of knowledge, which also intersects the increasingly common view that archaeological knowledge is inherently political (McGuire 2008; Matthews 2009). Finally, QualGIS situates multiple forms of quantitative and qualitative data alongside one another. The inclusion of qualitative data within a GIS requires a nuanced attention to detail as the act of translating various forms of historical knowledge into geospatial formats can result in the loss of qualitative meaning (Schuurman 2009). Historical archaeology's unique approach to situating artifactual, documentary, and ethnohistorical data alongside one another means that the discipline has been undertaking this sort of work for half a century. An IQ-GIS allows users to step inside a 3-D site map and access the multiple datasets driving archaeological interpretations. Game engines allow these multiple interpretations to be situated alongside one another. These alternative interpretations can replace one another in the virtual world environment or be superimposed on the reconstructed landscape, as illustrated in Figure 8. IQ-GIS can also address the political nature of archaeological research. The multiple interpretations support a more inclusive archaeology by sharing the archaeological process with stakeholders.

The incorporation of qualitative data is a crucial step in realizing historical archaeology's long-term potential regarding GIS. This is partly due to the growing interest historical archaeologists have in regard to engaging stakeholders through the research process (McDavid 2002; Colwell-Chanthaphonh and Ferguson 2007; Castañeda and Matthews 2008; Silliman 2008; Atalay 2012; Purser 2012). Historical archaeologists who engage P-GIS and counter-mapping draw upon accessible methods for addressing pressing issues in the collaborative exploration of the past (Harrison 2011). One challenge facing this type of work is that it does not line up with traditional modes of scholarship, where the focus remains on concentrating expertise in academic hands. The ability to inform scholarly interpretations with non-elite views offers archaeologists powerful new directions regarding interpretation and community engagement. One reason these approaches have not received more attention from historical archaeologists may be the lingering conflation of GIS with positivist science and environmental determinism. GIS is not synonymous with quantitative analysis, nor should it be seen as inherently producing authoritative views of the past. The representational capabilities of GIS are more than sufficient for collecting, analyzing, and displaying multiple, even contrasting, views of the past.

The true scope of GIS's mapmaking capabilities are typically underutilized by archaeologists. Maps are powerful representational objects. They shape the way we archaeologists think about ourselves and one another. They influence how we experience our local environments. Much of this power rests on the act of naming. The common perception of maps as authoritative rests on their perceived objectivity. They naturalize artificial, culturally defined constructions (e.g., political boundaries). We historical archaeologists are not alone in our desire to incorporate multiple perspectives into our maps (Mogel and Bhagat 2007; Thompson 2008; Cope and Elwood 2009). Here lies the intersection between participatory democracy and cartography. The process of mapmaking is fluid, and counter-mapping pushes cartography to explore new representational strategies. The growth of open-source GIS in the last generation makes these possibilities more accessible to a wider range of researchers and communities. Unfortunately, some archaeologists dismiss mapmaking as a rudimentary aspect of archaeological GIS. In truth, working with communities to map accurately the multiple ways they experience their natural, built, and social environments represents an important way to empower communities (Rattray 2015). Democratizing maps in this way represents a powerful tool for collaborative archaeology, and the visualization of historical inequality provides an accessible way for communicating the ongoing social inequality in today's world (Figure 7). Like artifacts, maps are powerful objects capable of connecting people to other times and experiences in immediate and emotional ways. Ultimately, realizing the full potential of GIS's visualization potentials for historical archaeology faces similar challenges regarding the creation of IQ-GIS, exploration of simulation, and even basic GIS techniques already in practice.

How historical archaeology is taught and practiced is perhaps the key challenge regarding the discipline's utilization of GIS. Addressing these pedagogical issues requires more historical archaeologists to engage critically with the technology. While the majority of historical archaeologists will not become proficient users of GIS, in an era of big data archaeology has a tremendous role to play (Llobera 2011). Llobera is particularly focused on the ways archaeology should intersect these larger trends and specifically urges archaeologists to engage with data visualization. In his view, archaeological computing as a whole has yet to develop into a coherent subfield of archaeological practice and remains outside the "well-established curriculum within archaeology" (Llobera 2011:216). Too few archaeology students are encouraged to engage and experiment with geospatial technologies. This is peculiar, as archaeologists have developed robust interdisciplinary practices in the past. Geoarchaeologists, zooarchaeologists, and bioarchaeologists are regularly encouraged to develop deep levels of understanding regarding other disciplines. If geospatial technologies are going to attain the same level of sophistication and disciplinary acceptance as geoarchaeology or zooarchaeology, then it becomes necessary "for some archaeologists to attain what some authors refer to as an 'amphibious state' … a state that will enable them to move from one discipline to another" (Llobera 2011:218). In regard to GIS and historical archaeology, such an amphibious state will support the development of novel insights regarding the application of geospatial technologies to archaeological research. Archaeologists who fail to develop this expertise limit their own understanding of the technology's potential. If GIS is only used for those forms of analysis regularly undertaken by others, then opportunities for innovation are missed. The amphibious state Llobera references has yet to occur, and its absence hampers the discipline's appreciation of the true potential for GIS. This has the unintended consequence of restricting students from expanding their career prospects and contributes to entrenching further the academic/professional divide. I have heard archaeologists compare GIS to other software (e.g., Microsoft Office), but GIS is more than a program. As feminist geographers note (Cope and Elwood 2009), GIS is a social practice. As with other practices, we archaeologists must guard against complacency and inertia. As a discipline, we need to encourage the same levels of methodological exploration with GIS that we accept with excavation, field survey, and artifact analysis. Until then, we will remain in the role of passive consumer, uncritically applying techniques developed by different disciplines and for different contexts to our work.

Conclusion

This article joins others in this special issue of *Historical Archaeology* in celebrating the 50th anniversary of the Society for Historical Archaeology. My hope with this contribution is that other archaeologists reading it will be alerted to the exciting work of their colleagues who are seriously engaging with the potentials of GIS for this discipline. In addition, I have attempted to predict some areas of potential growth. I believe historical archaeology is capable of pioneering work in regard to archaeological GIS. Realizing these potentials will require specific pedagogical and disciplinary shifts. These shifts will occur as more historical archaeologists develop their geospatial toolkits and apply them to new contexts with the full realization that GIS is a practice, not simply a skill. This will in turn support more robust pedagogical strategies wherein historical archaeologists in academic settings interact more directly with GIS in their research, teaching, and scholarship. Fortunately, there is improved access to computer technology and increasingly intuitive versions of GIS software. There are also more nuanced and rigorous theoretical treatments of the technology to assist in exploring its potentials.

The use of GIS by archaeologists is typically divided into three broad categories; inventory, spatial analysis, and mapmaking. Historical archaeologists continue to explore each of these aspects, with the majority continuing to focus on inventory and basic forms of spatial analysis (e.g., viewshed analysis). While these forms of archaeological GIS remain central, shifting the discipline's focus toward more advanced forms of analysis, as well as acknowledging the importance of mapmaking, are important directions for the future. These directions take advantage of historical archaeology's reliance on multiple forms of data to explore wholly new forms of geospatial analysis and representation/data visualization. Reliance on multiple lines of evidence means that historical archaeology occupies a unique position regarding novel applications of GIS. These include nuanced engagements with P-GIS and counter-mapping to foster a more inclusive archaeology. The exploration of IQ-GIS and computer simulation will allow historical archaeologists to lead the way in developing new methodological approaches to historical scholarship. Realizing these potentials represents a reversal of the current practice, which largely sees historical archaeologists as passive consumers of techniques and methods developed by researchers working in different temporal contexts. The next 50 years of historical archaeology will witness the development of incredible technologies. As I write this article VR technologies (e.g., Oculus Rift) are on the cusp of becoming viable commercial products and will most likely be widely available by the time this article is published. The intersection of VR and IQ-GIS represents a watershed moment in public archaeology. For the first time archaeologists will be able to posit alternative interpretations of archaeological data in formats available to an ever-growing segment of humanity. Historical archaeologists who seriously engage with the full range of geospatial technologies and analytical techniques will also serve as a bridge between the social-sciences and humanities disciplines, as well as pioneer new modes of civic engagement with diverse publics. Historical archaeologists who work with GIS combine two exciting domains: the study of the past with the exploration of emerging technologies. For those of us who work at this intersection, the future of the past has never been brighter.

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