A Method for Determining Damage Within Historic Cemeteries: A First Step for Digital Heritage

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A METHOD FOR DETERMINING DAMAGE WITHIN HISTORIC CEMETERIES: A FIRST STEP FOR DIGITAL HERITAGE

by

JUSTIN MALCOLM

A thesis submitted in partial fulfillment of the requirements for the Honors in the Major Program in Anthropology in the College of Sciences and in the Burnett Honors College at the University of Central Florida Orlando, Florida

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ABSTRACT

While it is true that historic cemeteries are places that contain a wealth of knowledge about the history of a community they are sometimes not well maintained. The information within can be lost as grave-markers are damaged either by natural causes or human interaction. In larger cemeteries preserving these significant places can sometimes be difficult due to a number of different factors. Therefore focusing preservation efforts on specific locations where damage is more likely to occur is crucial to ensure that the monuments that are the most at risk are preserved. One possible way of accomplishing this is through the utilization of a geographic information system (GIS) to determine the shortest distance path an individual may take to reach a specific grave-marker. This can be accomplished by conducting a near analysis between an origin point and every grave-marker. These paths would also show each grave-marker that an individual passes indicating the potential for purposeful or accidental interaction. With this information efforts such as photogrammetry can be applied effectively for digital heritage preservation. Such methods would permit individuals to manipulate three-dimensional representations of grave-markers in order to preserve a large portion of the information it contains.
Dedicated to Thomas and Nathalie Farron
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Finally, I would like to thank Mr. Don Price, the former Sexton of Greenwood Cemetery for allowing me to have access to the cemetery for this research.
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CHAPTER 1: INTRODUCTION TO DIGITAL HERITAGE AND GREENWOOD CEMETERY

INTRODUCTION

Often times forgotten when considering what areas are historically or anthropologically significant, cemeteries are hubs for information associated with a community. They give a glimpse into the lives of those who are now interred within. These monuments can contain information ranging from names, birth and death dates, family relationships, or an affiliation to a religious or fraternal organization. Even an individual's social status can be assumed based on the materials used or the size of the grave-marker. However, the sacred places that house the bodies of the deceased may not be well documented. James Stein discusses this by stating, “A lot of times, information about cemeteries just is not well-documented. It stays there in maps that are hand-drawn, history databases or someone who runs the cemetery knows it” (Church 2009). The information that is present can also be difficult to obtain or may cease to exist when a knowledgeable individual passes away. This loss of information could even be caused by accidental damage caused by visitors within the cemetery. Pedestrian traffic within these historic places is potentially hazardous to the grave-markers. This can be due to damage that might occur either intentionally or unintentionally from people walking by these monuments. The Texas Historical Commission (2011:2) states “cemeteries are among the most valuable of
It is of critical importance to ensure that the information that is contained within these locations is preserved.

Unfortunately, in larger cemeteries there can be thousands of graves present. This can make it difficult to determine where potential damage could occur before it happens. This research will address whether it is possible to predict pedestrian traffic patterns that could cause damage to grave-markers within a cemetery. By utilizing geographic information systems (GIS) a spatial analysis can be conducted to accomplish this task. This will allow for the better identification of pedestrian movement that may lead to identifying areas of increased potential damage. This will then allow for the information associated with the grave-markers to be digitally preserved. I hope to determine a way to better identify these areas of increased potential damage by discovering if there are patterns that can be observed within the sections of a cemetery. To accomplish this I will be conducting a spatial analysis to determine potential pedestrian traffic patterns. The analysis will display the shortest path an individual could take from where they park their cars to the specific grave-marker that they are visiting. For this analysis, I will be looking at Greenwood Cemetery, located in downtown Orlando, Florida. I will focus on three specific sections of this cemetery. These sections have distinct shapes to their layout but a roadway surrounds them all. This allows visitors to drive their vehicles to the specific section they are going to visit without having to walk through other sections. My desire for this work is to develop new methods that can help predict locations of increased potential damage. With this knowledge, steps can be taken to digitally preserve these grave-markers that are at potential risk.
BACKGROUND

Greenwood Cemetery is located in downtown Orlando, Florida (Figure 1). It contains both historic burials dating back to the 1880s and modern burials. It is still an active cemetery. According to Eve Bacon, before Greenwood Cemetery was created families in the Central Florida area would simply bury their deceased in small cemeteries or on family land (Wardlaw 2009:13). Currently, Greenwood occupies a considerable amount of land. It originally consisted of 26 acres (Wardlaw 2009:13), but it now encompasses more than 100 acres (Gillespie 2018). The cemetery is divided into isolated sections with the older burials being located on the southern end of the property and the newer burials on the northern end. These sections are divided by paved roadways that weave through the cemetery, allowing individuals to drive close to the location of the grave that they are visiting. These roadways not only add convenience for guests to travel to the specific section they’re visiting, but they also make it easier to isolate where damage could occur from pedestrian activity (Figure 2).
Figure 1: Outline of Greenwood Cemetery in reference to the surrounding downtown area displayed using a high-resolution orthoimage of Orlando, FL, obtained from USGS EarthExplorer
Figure 2: Greenwood Cemetery plot map depicting the location of each section under analysis outline (City of Orlando 2018)
With different sections in Greenwood possessing so much significance and the presence of roadways dividing them from one another this is the perfect place to conduct this analysis. The objective of this research is to demonstrate the potential of the proposed methodology. Maps of three sections of Greenwood Cemetery will be created. This will be used to find the shortest distance paths from the roadway to each grave-marker within each section in order to help determine the areas where damage may occur. Once these paths are defined it is possible to view a count of each time one of the paths intersects with a specified area around each grave-marker. This provides an estimate of the likelihood that damage might occur to that grave-marker. From this information, a percentage of grave-markers can be chosen for digital preservation efforts, though that additional work lies outside the bounds of this present study. The GIS software ArcGIS, produced by ESRI, will be utilized to conduct this spatial analysis.

Greenwood Cemetery is much more important than just a generic location for this analysis to be conducted. It holds a tremendous amount of significance to the history of Orlando and to its citizens. Within this cemetery, many prominent figures in Orlando’s history are interred, giving glimpses into the city’s past and displaying the importance of the cemetery to this city. Among those of note in the cemetery are former Mayors of Orlando. One such individual, Mr. Carl Langford, became mayor in 1967 and served in this position for 13 years. During this time, he negotiated the purchase of land where the Orlando International Airport would be built (Orlando Sentinel 2011). This airport is now one of the largest in the nation, demonstrating the international importance of his actions. Mr. Langford was also Orange County’s first selective service draftee during World War II
(Orlando Sentinel 2011). Another notable figure that is interred within this cemetery is Mr. Francis W. Eppes VII, buried in the Eppes-Shine plot, which is marked as a Florida Heritage site. Mr. Eppes was the grandson of Thomas Jefferson and moved to Orlando 1869 to live out his final years (City of Orlando 2015). However, his impact on the community was much more substantial than this as he helped establish what is now the cathedral of St. Luke’s (City of Orlando 2015). Greenwood also includes the grave of Thomas Gilbert Lee, the man who founded T. G. Lee Dairy in Orlando, Florida in 1925 (Dickinson 2012). The area around this Dairy plant is now known as the Milk District, which is a distinctive part of downtown Orlando (Dickinson 2012). T. G. Lee dairy is still the largest dairy plant in Central Florida and it was reported in the Orlando Sentinel that at “the 50th anniversary of T. G. Lee’s Dairy, nearly 1,000 people gathered at Walt Disney World to pay tribute to him” (Dickinson 2012). Greenwood Cemetery includes prominent members of Orlando’s history, individuals who have truly made an impact on the city of Orlando up to the present day.

Beyond interring prominent past members of Orlando’s community, Greenwood Cemetery has significance to the city in general. Numerous unmarked graves date from Orange County’s dark past of segregation where the act of lynching was unfortunately too present. As reported by Vibert White in the Orlando Sentinel “Orange County was well known as a place where lynchings were a common form of murder and intimidation” (Kunerth 2015). According to White Greenwood contains a section with unmarked graves of black citizens who died from lynching (Kunerth 2015). This use of Greenwood Cemetery, while incredibly tragic, still remains a crucial part of this specific history. Even more recently, the city of Orlando offered plots within Greenwood Cemetery to the victims of the
Pulse nightclub shooting in 2016 (Weiner 2016). In the wake of this tragedy, members of the community came together and Greenwood Cemetery was involved in the community response. These examples show why Greenwood Cemetery stands out as a place of significance to many different communities within Orlando.

Greenwood Cemetery has played a crucial roll not just within Orlando history but also within United States history. Within Greenwood Cemetery, burials of military veterans from the Civil War up to the present can be found in different portions of the property. Specific subsections of the cemetery are even devoted to the dead from particular wars. Within one of the sections of Greenwood Cemetery that were chosen for this thesis, section I, there is a plot containing the graves of Union veterans from the U.S. Civil War from the Grand Army of the Republic (GAR). There is also another plot in the section across from this one, Section J, which houses the burials of veterans who belonged to the confederacy. This plot is labeled as Daughters of Confederate Veterans (DCV) on the Greenwood Cemetery plot map. Having the burials of these individuals next to each other, even though they were in opposing armies within the national struggle, shows the national history present within this cemetery.

Finally, Greenwood Cemetery provides many ways for the community to enjoy both the land that it occupies and the history that it houses. Greenwood Cemetery hosts moonlight walking tours, given by the cemetery’s sexton Don Price. He chronicles the history of the ca. 70,000 individuals who are buried within the cemetery (Dickinson 2015). By spreading the stories of the individuals who are buried in Greenwood Cemetery, their history and their involvement within the community can live on. However, visiting the
resting places of family and taking this tour is not the only reason individuals visit the
cemetery. With the Greenwood Urban Wetlands located right next to the cemetery, and the
presence of wildlife within the cemetery, photographers also make use of the cemetery
grounds. Both owls and eagles are present within the cemetery during certain times of the
year (Rosack 2011). The accessibility that the public has to this important place is one
further reason to conduct this analysis within Greenwood Cemetery. The presence of
visitors of all kinds on the grounds can lead to damage to the grave-markers.

DIGITAL HERITAGE PRESERVATION AND PHOTOGRAMMETRY

The use of GIS for cemetery management and preservation is not a new concept.
Cemeteries have utilized it in several different ways. The Pennsylvania Historical &
Museum Commission (2015) explains one use for GIS within cemeteries stating that maps
can be used to mark the locations of grave-markers in a cemetery. GIS can also provide a
much friendlier user experience for visitors. We can see this utilization of GIS in the
research conducted by two graduate students from the University of Wisconsin-Platteville
(Hamer 2014). They were able to provide a map that can be queried to find the location of
specific graves. Photographs can be combined with such maps to help assess the overall
conditions of the grave-markers within a cemetery (Neal 2008:3). GIS has also been
combined with ground penetrating radar (GPR) surveys. An example of this can be found at
Greenwood Cemetery. A former master's student at the University of Central Florida (UCF)
utilized GPR within a GIS framework to see if there was a correlation between marked graves and their time of internment (Wardlaw 2009:3). All of these different methods display the range of GIS techniques that can be used to preserve monuments and assist with record keeping within historic cemeteries.

James Stein, a GIS Specialist at the National Park Service, advocates for the incorporation of data within a GIS for cemetery management, “Taking these historic texts and maps and combining them with GPS surveys and digital photography into a GIS allows for better management and long-term planning” (Stein 2006:2). Photographs, in this context, could be further expanded into 3D models constructed through a technique known as photogrammetry. Photogrammetry is defined as, “the process of creating 3D models from multiple images of the same object taken from different angles” (Azzam 2017). Using software such as Agisoft Photoscan photogrammetry can produce a digital reference from the time the photographs were taken. Individuals can view the model to see the condition of the grave-marker. They can rotate and manipulate the model and compare it with successive models to analyze deterioration or damage over time. Several researchers are currently practicing this technique of preservation and modeling within Greenwood, including myself. George Bevans, a professor from Queen’s University in Kingston, Ontario, discusses the utilization of this technique in Cataraqui Cemetery in Kingston, Ontario for the preservation of grave-markers (Church 2014). In larger cemeteries, there may be too many graves for this to be a practical method of management. That is why developing a methodology for determining where there is a higher likelihood of damage may be invaluable. It would allow cemetery managers to target photogrammetry to the most at risk
areas. While this is not the main focus of this thesis it is a viable tool for preservation that is fairly simple to learn. Therefore, it is worth mentioning as a follow up to this analysis.

Photogrammetry has seen broad and growing use within anthropology. In archaeology photogrammetry is a tool that is quickly becoming more important thanks to the software's increasing ease of use (McCarthy 2014:175). The process of photogrammetry in archaeology can be observed over a hundred years ago. Historically photogrammetry in archaeology has analyzed aerial stereo photography for archaeological site mapping (McCarthy 2014:176). Archaeologists used photogrammetry to reconstruct the ancient ruins of Persepolis in 1885 (Ebrahim 2014:4). More recently, in 2009 photogrammetry was utilized preceding construction in Weymouth, county Dorset, England to reconstruct a mass grave dating between AD910 and AD1030 (Ducke et al. 2011:375). Photogrammetry even has practical applications in forensic archaeology. Kevin Gidusko, a former master’s student at the University of Central Florida, wrote his thesis on the use of close-range photogrammetry for recording skeletal remains at outdoor forensic scenes (Gidusko 2018). Regardless of how photogrammetry is being applied, it is a phenomenal way to produce a cost-effective high-resolution reference model that can be viewed and manipulated in three dimensions (Magnani et al. 2016).

The process of producing a photogrammetric model is not necessarily difficult, but it can be time-consuming. It requires an individual to accurately take photos that can be successfully processed by software. Photogrammetry can be used on different scales. It can be used for three-dimensional modeling of artifacts (Porter et al. 2016). However, it can also be used to digitally record monuments and even full sites. One such site is located in
the Jezreel Valley, Israel, which uses photogrammetry for a range of activities such as producing accurate site plans so that measurements can be taken and then later used for mapping and visualizing features (Prins 2012). Combined with GIS tools photogrammetry's applications range from creating a map of a site to planning a future expansion of a cemetery. In County Galway, Ireland, the company Impact GIS utilized drones to assist with photogrammetry in order to produce a ground surface model of a cemetery and the surrounding area (Impact GIS 2018). They created a visual representation of the location in order to determine if a proposed expansion would potentially impact an early Christian enclosure. These wide ranging applications show the adaptability of photogrammetry. While this is clearly an incredibly useful tool it will not be used on a large scale within this thesis. However, it could be utilized as a possible follow-up application for monuments that are identified as at risk through the analysis that I am conducting in this thesis.
CHAPTER 2: ANALYSIS AND FINDINGS

METHODOLOGY

To begin conducting this spatial analysis a map of Greenwood Cemetery must be acquired to use as a base layer within the GIS. To obtain this map I turned to a website known as Earth Explorer, which is operated by the United States Geological Survey (USGS). From here I was able to download a high-resolution orthorectified image with a pixel size of half a meter. This type of image is described by the USGS (2015) as, “a uniform-scale image where corrections have been made for feature displacement such as building tilt and for scale variations caused by terrain relief, sensor geometry, and camera tilt”. This is required when working in places where numerous trees are present, such as Greenwood Cemetery. This type of aerial photography works to correct issues potentially caused by trees, which would obscure large portions of Greenwood Cemetery making it impossible to distinguish the locations of many of the grave-markers. Another benefit of using this higher resolution image is that while viewing the map it is possible to zoom in to better distinguish the location of as many grave-markers as possible.

Once this map has been acquired, a shapefile can be created so that a visual representation is provided for the grave-markers in the three sections under analysis. A polyline surrounding each of the three sections is also created to symbolize a possible origin point for visitors along the roads (Figure 3). Each section has a different total number of grave-markers present within it allowing for variation in sample size to be
tested. I have assigned each one of these sections a number one through three as a means to distinguish them. I did this rather than having a mix of letters and numbers, which is how the Greenwood Cemetery plot map is labeled. These sections were chosen based on the two criteria. The first of these was to select sections that would provide differences in the layout of the grave-markers. The second criterion was to choose sections that had a roadway around them.

After these shapefiles are created, spatial reference information needs to be added to the shapefile's attributes table. An attribute table is a chart that contains the data that is associated with a specific shapefile. This includes X and Y coordinate data, which gives each grave-marker a spatial reference on the map. In order for this to be done the projection function was conducted for each of the shapefiles that were included in the analysis. The specific projected coordinate system for these shapefiles will be in WGS 84 / UTM zone 17N, which is the Universal Transverse Mercator (UTM) zone where Florida is located. The reason for using the UTM coordinate system for this analysis is because it uses a square grid system. This means that there is a precise constant relationship between distances on the map. Along with this the USGS (2001:1-2) states there are no negative numbers and the coordinates are decimal based. Once the spatial reference is created the “add XY coordinate” function can be used for the shapefiles in the analysis. This will produce the X and Y coordinates for each of the grave-markers that are present in the three grave-marker shapefiles. Having this information in the GIS is crucial since it will provide the spatial reference that is needed for the rest of this analysis.
Figure 3: Section one with points representing grave-markers and the origin polyline
The next step in the process is to conduct a near analysis between each set of grave-markers and the origin polyline that is associated with it. The purpose of this analysis is to produce the data necessary to determine the shortest possible path that an individual could take from the roadway to a grave-marker. This analysis will produce three columns in the attribute table for the grave-markers “Near_X”, “Near_Y”, and “Near_Distance”. This will present the X and Y coordinates of the closest point on the origin polyline and the distance in meters for the shortest distance path that an individual can take from the origin point to the grave-marker. These paths will be used to determine the increased possibility of damage occurring to a grave-marker based on the concept that more close interaction, even indirect interaction, could lead to damage.

This analysis is the most efficient method to choose due to Florida’s low change in elevation. Another method that could be utilized to conduct the analysis proposed in this thesis is a “least-cost path” analysis. An analysis that uses topographic information could potentially enhance the results acquired in certain cemeteries that have variation in slope. However, this analysis is unnecessary in a location that has almost no variation in slope, such as Greenwood. Therefore, a “near” analysis will produce results similar to what a “least-cost path” analysis would produce in this case. Even in areas where there is high topographic variation a “near” analysis would still yield good results over short distances.

Once this data has been collected, a visual representation of these shortest distance paths can be produced from the polyline of the roadway to each grave-marker. To make this visual representation, an “XY to line” function is necessary to draw the shortest distance paths based on the data collected from the near analysis (Figure 4). These lines
are more important than just a visual representation because they will be used to count the number of times a path will pass by a grave-marker. This count in turn indicates the possibility for human interaction and damage to occur. For these path lines to be counted, buffers were created around each grave-marker and set to a one-meter area around the grave-markers (Figure 5). A one-meter buffer was placed around each grave-marker because it fully surrounds smaller grave-markers and still encompasses the larger grave-markers that are present. This one-meter buffer would also take into consideration that smaller grave-markers might be harder for an individual passing by to see compared to larger grave-markers. Meaning that an individual could be more likely to accidentally walk in proximity or even into a smaller grave-marker.

Finally, to automate the counting process for each time a path intersects a buffer, a “spatial join” between the attribute tables of the buffers and the shortest path lines must be done. This will add new columns in the attribute table that will display the line count for each intersection and the corresponding ID numbers for each grave-marker. Once this new column has been added to the attribute table, the field calculator can be used to subtract one from each intersection count to account for the line that goes directly to the grave-marker that the buffer is surrounding. This makes the organization and interpretation of the data much more efficient because the intersection count can be ordered in ascending or descending order of risk. This also allows me to select and highlight grave-markers based on their intersection count. The buffers can be highlighted in either the attributes table or visually on the Greenwood Cemetery map to distinguish them from the other buffers in that section of the cemetery.
Greenwood Cemetery Map 2

Legend

Grave_Set1  Poly_originUTM1

XY_Graves_1

Figure 4: Section one with shortest path lines displayed between grave-marker points and the origin polyline
Figure 5: Section one with buffers included around each grave-marker
RESULTS

The result of this analysis produced a way to see each shortest distance path to the grave-markers in all three sections. It also simultaneously displayed the count for each time a line passed within close proximity of a grave-marker based upon an intersection with a buffer. By displaying these paths and how they intersect with the buffers, we can see where increased human interaction may occur that could potentially cause damage. This provides the opportunity for an individual to analyze this information and then determine the most productive method for digitally preserving grave-markers by narrowing down the areas that need attention. From the attribute table produced in the analysis the field calculator can be utilized to determine the top percentage of likely at risk grave-markers. For the purpose of this thesis, a subset of the top ten percent has been chosen to evaluate. This percentage was determined based on the time it would take an individual to produce accurate models for digital preservation. The sections within Greenwood that are being evaluated have a substantial number of grave-markers present. However, this percentage can be increased or decreased based on the needs of the cemetery it is being used in and the desired result of the individuals who are working to preserve the grave-markers. These subsets provide a more manageable number of at-risk grave-markers for which preservation efforts, such as photogrammetry, can be applied to help to ensure that a lasting archival record will be produced.

The three sections chosen for this analysis were selected based on the presence of different patterns in the arrangement of grave-markers that could be seen from the aerial
photograph. The overall benefit of having this differentiation in the positioning of grave-markers is that the variation might reveal different areas of potential risk for damage to occur within each section. Each section is also located in a different portion of the cemetery, which is important because different areas in the cemetery contain grave-markers from different time periods. Each section also has a different number of grave-markers present within it and they vary in size, as well as, the distance between each monument. These are all factors that need to be taken into account when looking at the data for each section individually, as well as, comparing each section to determine how the layout can impact the locations of potential damage risk.

The section that I have labeled as section one, section S on the Greenwood Cemetery plot map is located centrally within the cemetery. This section has a somewhat uneven dispersal of grave-markers that appear oriented more towards the center of the section. Rows are not clearly defined in this section. With the layout being less clearly defined, it is crucial to determine areas of increased risk so preservation can take place efficiently. Within this section of the cemetery, there are a fair number of more modern grave-markers present, which might result in more visitors coming to that specific section. With the presence of more recent grave-markers alongside older ones it would be interesting to see if there are any correlations between what grave-markers are present in the areas where increased damage could occur.

Section two for this analysis labeled as section nine on the Greenwood Cemetery plot map, is located at the northern end of the cemetery. This is where many of the more recent graves are located. This section is well organized with the grave-marker’s layout
clearly defined by rows in the center. However, there is also the presence of grave-markers outlining the section. With many of the more recent grave-markers being present in this section, it could be assumed that more visitors will be entering this section than ones that contain older burials. Even though these are not historic burials, a comparison between a section containing more recent internments is still beneficial for this study. With the information from this section, a comparison can be made between section one, with a less organized layout, and section two with a well-organized layout in rows. It will be interesting to see where damage is predicted to occur within these different sections.

Finally, the third section being evaluated, section I on the Greenwood Cemetery plot map, contains several different layout patterns for its grave-markers. This section is the furthest south of the three sections, meaning that older burials are present within it. Located within this section is the plot belonging to the Grand Army of the Republic. The layout of grave-markers within this section is substantially different from the layout in other sections in this analysis. This is due to the Grand Army of the Republic subsection forming the shape of a triangle, with multiple rows forming smaller triangles within it. There is also a subsection within section three that is comprised of clearly defined rows located relatively close to the center of the section. However, many other grave-markers are oriented in a manner resembling rows oriented north south towards the center. With this variation in grave-marker layout, it is predicted that specific patterns in damage risk should occur for each subsection within the section.

For the section that I labeled number one, I chose to display the top 40 at-risk grave-markers out of the total 402 (Figure 6). This number is right around ten percent of the total
and allows for a large enough sample size to view noticeable patterns of at-risk grave-markers within the section. This demonstrates that the method works, and would allow individuals working to digitally preserve these grave-markers the ability to focus on specific subareas of the section. Clustering can be noted among the highlighted buffers that indicate the grave-markers that are within the top ten percent for risk of damage. This indicates areas that might be more at-risk within the section. Interestingly, while there are many grave-markers closer to the roadway, not all of them are indicated as at-risk in this analysis. In fact, it can be seen that some of the more at-risk grave-markers are closer to the center of the section. By looking at the shortest distance path lines, it can be seen that the grave-markers that are highlighted are typically in line with a number of other grave-markers as one moves to the center of the section. This means that the layout can affect the results, with how many other grave-markers are in line with each other being a type of pattern that leads to greater risk. This makes proximity to the edge of the section less of a concern than the presence and location of other grave-markers. The northern and southern portions of section one display this tremendously well. It can be seen that the grave-markers with highlighted buffers produce columns leading towards the center of the section. With this information, digital preservation can be conducted on the grave-markers indicated to have a higher risk of human interaction.
Figure 6: Results of a subset of ten percent of the total grave-markers highlighted on the section one map in ArcMap
When looking at the highlighted buffers for the top ten present of at-risk grave-markers for section two, we can see a fairly clear distinction for the monuments that are at-risk in this section. It is apparent that grave-markers running along the perimeter of the rows may be generally more affected than those in the interior of the section. This is simply because the layout of this section results in more interior grave-markers being in line with those on the perimeter. There are exceptions to this, such as the single grave-marker towards the east side that lies closer to the center of the section in comparison to other highlighted grave-markers. Along with this, the grave-markers that are closer to the roadway in the corners of the section do not have as many closest path lines going by them due to their proximity to other grave-markers. In this section, there were a total of 281 grave-markers, which means that a ten percent subset produced a total of 28 grave-markers to focus on (Figure 7). The results show that the pattern still follows the same concept that was seen in section one. If a grave-marker has more grave-markers in line directly behind it, then it will likely be more at-risk for individuals to pass by it. With a more clearly defined layout in section two, it becomes easier to predict where those grave-markers will be located.
Figure 7: Results of a subset of ten percent of the total grave-markers highlighted on the section two map in ArcMap
Due to the presence of several different layouts of grave-markers within section three, there appear to be several areas of increased potential risk of damage (Figure 8). The placement of these areas seems to be linked to the different layouts in different areas of section three. The likely reason for this result is because of the individual layouts of the subsections. With this information, areas can be distinguished showing where grave-markers have increased potential for damage. This is clear when looking at the Grand Army of the Republic section and the other subsection that possesses clearly defined rows. In both cases since the highlighted areas have grave-markers directly behind them, there is a higher potential for pedestrian traffic and potential damage to occur. While other grave-markers in these sections are closer to the roadway, the highlighted grave-markers are in areas that have a greater number of monuments in close proximity within one area. However, it appears that the area within this section that is most at-risk is the southern area of the section. More than likely, this is due to the presence of clearly defined rows of grave-markers in the southern area extending towards the center of the section. This indicates that a subsection’s proximity to another subsection can also impact the results. A total of 411 grave-markers are located within section three and the 41 highlighted buffers represent the top ten percent of at-risk grave-markers. As with sections one and two, clusters of at-risk grave-markers derived from this analysis represent areas where preservation efforts can be focused to more efficiently address potential damage concerns within this section.
Figure 8: Results of a subset of ten percent of the total grave-markers highlighted on the section three map in ArcMap
It is interesting to note that while it might be assumed that grave-markers that are closer to the roadway will be more at risk for potential damage, it is not always the case based on this analysis. Many of the grave-markers that are near the roadway do have a higher risk for potential intersection with pedestrian traffic and the damage it might cause. However, there are still many other grave-markers near the roadway that have low relative intersection counts. This is due to the layout of the sections and the arrangement patterns of grave-markers within it. While being closer to where someone enters the section plays a part in the potential for human interaction, there are other factors that can better determine if an individual passes a given grave-marker. This includes a clear result that a linear placement of grave-markers can increase the risk of damage. From the results of this analysis much can be learned in terms of cemetery planning. With the ability to potentially determine where areas might be prone to damage sextons can better plan for the addition of future burials. This includes the positive and negative effects of how grave-markers are arranged in relation to each other. Section three could provide this insight due to the varying arrangements within the section (figure 9).
Figure 9: Section three with varying percentages of potential risk represented by color-coded buffers
By analyzing and comparing varying percentages of potential areas of risk for Section Three, seen in Figure 9, patterns of the arrangement of areas more prone to potential damage become more clearly distinguished. When looking at the map the highlighted buffers have been color-coded to correspond with specific percentages. Buffers highlighted in green represent the top 5% of potentially at risk grave-markers, yellow highlighted grave-markers represent those between 5% and 10%, and red highlighted grave-markers represent those between 10% and 15%. When analyzing the areas highlighted with green and yellow buffers, it can be seen that the areas with more green generally fall in closer proximity to the roadway in comparison to the areas with more yellow. This relates to the linear arrangement of grave-markers. However, with the addition of a higher percentage of potentially at risk grave-markers, more areas of focus start to emerge. These areas are generally further towards the center of section three, but also appear in new areas near the roadway. Single grave-markers are also now more easily interpretable within the overall layout of the grave-markers.

Based on the results collected in this analysis it is apparent that the layout of grave-markers will determine the areas that have a higher potential of risk. However, a comparison between all three layouts shows that certain arrangement patterns of grave-markers will yield areas of higher concentration. In section three the subset of grave-markers near the center of the section that formed more clearly defined rows has a high number of linearly placed grave-markers. However, this area has fewer overall highlighted grave-markers present compared to the southern portion of the section, which also contains linearly placed grave-markers that are arranged in rows running north to south.
While both of these areas have linearly placed grave-markers the ones running north to south form more clearly defined rows perpendicular to the roadway compared to the area near the center. This can also be seen in section one where areas with more potential risk for damage are in arrangements of clearly defined linear rows rather than in other areas that lack a more clearly defined arrangement. However, in section two, which has a more organized layout overall, the grave-markers that have a higher potential risk for damage are more frequently located closer to the roadway. These grave-markers still follow a generally linear placement, in terms of other grave-markers behind them. However, the proximity of these grave-markers to the ones behind them appears to be a determining factor. This becomes clear when evaluating other grave-markers that are not within the most at-risk grave-markers within section two and comparing the distances between the grave-markers.

While these results and this method are focused on predicting accidental human damage to grave-markers within a cemetery, damage can occur in other ways. Natural causes, such as weather and time, can also have a large impact on the long-term preservation of grave-markers (Wilson 2016:6). Along with natural causes, there are other factors that could potentially lead to increased damage to grave-markers. One of these potential causes could be intentionally directed damage to a specific grave-marker. This is impossible to account for in this analysis. Even the use of the roadways could cause issues. This could occur if individuals accidentally deviate from the paved path while driving, despite signs being posted. While different methods would be needed to focus on different causes of damage and deterioration, all would work towards the same end goal. These
various methods, including the one proposed here, could be combined into an overall risk prediction toolkit within GIS.

During the research process, I found that there are limitations within different aspects of the method’s data collection process. One of these limitations is that while it was simple to acquire a base map by downloading a high-resolution orthorectified image from EarthExplorer, the image that was acquired to act as a map was produced in 2011. This means that there is the possibility that there are differences between what is present on the map and what is currently present at Greenwood. It was also difficult and time-consuming to locate all of the graves-markers that were present on this map. This is due to the many trees present within Greenwood Cemetery and even the variation in ground color that might obscure the grave-markers. While it was possible in this case to visit the cemetery in an attempt to determine where these grave-markers might be on the map, it is still a limitation. Working with a cemetery that has coordinate data for its known grave-markers would be a best-case scenario. In certain cases, it could be difficult to obtain the files containing this information. Additionally, in an active cemetery like Greenwood Cemetery updates to the dataset would need to be done periodically. Using the method in this study with such periodically updated data would allow individuals managing the cemetery to see how new burial locations might impact all the grave-markers in that section.

A second limitation in the method used in this study is that it does not incorporate information on the topography of the cemetery. In the case of Greenwood Cemetery, there is little variation in slope. However, a broader “least-cost path” analysis could be
undertaken in more topographically diverse cemeteries. Such an analysis would define the least-cost path between an origin point and a destination point in relation to the cost specifications across differing slopes, rather than straight-line distance. Since Greenwood Cemetery is relatively flat, other than one significant slope, the simple “near” analysis produced sufficient results for this study.

Finally, due to the nature of this analysis, assumptions had to be made, which can either be seen as a limitation or beneficial depending on who is conducting the analysis. One assumption is the origin points where individuals would possibly enter each section. It is difficult to predict human behavior and this study used the nearest location from each grave-marker to the roadway as a simple way to predict these points. This methodology is meant to be simple enough to be utilized even by those with a basic understanding of GIS. However, because of this simplified analysis, obstacles such as trees and other foliage within Greenwood are not digitized and some pedestrian traffic paths incorrectly pass directly through them. In addition, by utilizing a near analysis to produce the shortest paths between the roadway and each grave-marker, problems could also emerge. This does make it easier for new GIS users to be able to conduct this analysis. However, because of this, users would have to closely examine whether or not direct route paths are moving through impassable areas and thereby biasing the results.

The end goal of selecting the most at risk grave-markers with this analysis is to allow managers to better focus preservation efforts on the most at-risk monuments before damage can occur. Identifying these monuments is only the first step. This could be followed by producing an archival reference of the current state of the monument, using
methods such as photogrammetry. A photogrammetric model can capture a tremendous amount of detail. I have included a model that I have produced in the past that displays a grave-marker from 1914 that is located within Greenwood (Figure 10). This grave-marker has suffered significant deterioration to the etchings on the grave-marker. The presence of moss and other substances obscures part of the grave-markers face. It seems that the top portion of the grave-marker has also possibly been reattached. This can be assumed from the presence of a possible bonding material between the base and top portion.

Photogrammetry would also permit an individual viewing the model to manipulate it in a three-dimensional space rather than just looking at two-dimensional photos. This would produce a better representation when making a comparison over time to the changing states of the physical grave-marker. Ultimately, photogrammetry would allow the individual viewing the model to determine the extent of damage more accurately. This can be an incredibly beneficial resource. However, since it takes a long time to collect and process the photographic data into a photogrammetric model, it is crucial to narrow down and prioritize the number of grave-markers to which photogrammetric recording is applied. One such method for triaging this work is the near method that I have proposed in this thesis.
Conclusion

With the help of the GIS analysis conducted in this thesis and the use of photogrammetry the preservation process for historic cemeteries, such as Greenwood, can be done more efficiently. By locating areas that are potentially more prone to damage through the application of this thesis’ method of analysis, digital preservation becomes a
feasible option for busy sextants. With photogrammetry, a reference is created that can be used to track damage over time. Along with damage tracking, it is also possible to incorporate additional information directly from the grave-markers into the GIS. This information can include whom the grave-marker belongs to, the birth and death dates, and other notable features. By adding this information to the attribute table in a GIS for the more at risk grave-markers in a cemetery, this information is less likely to be lost. This is also beneficial in the long run for the management of the cemetery in comparison to paper records, which may be lost or damage.

The National Center for Preservation Technology and Training lists a guide with nine tips outlining how to conduct cemetery preservation. The fifth tip on this list is “prioritizing the work” (Striegel 2007). This study outlines one such methodology that could be used to accomplish this task. By conducting a spatial analysis to determine potential pedestrian traffic patterns we can determine areas that might attract potential increased damage. This would allow for a prioritization of work based on the areas where we can predict an increased potential for damage. From this information, digital efforts such as photogrammetry can become more feasible as a way to preserve these at-risk grave-markers. In larger cemeteries, where an optimal strategy is needed for efficient use of time, this type of analysis can be crucial for digital preservation efforts.
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