EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2018)
R. Sablatnig and M. Wimmer (Editors)

Short Paper

Deep Mapping Tarn Hows: Automated Generation of 3D Historic Landscapes

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Abstract

Changing landscape presents a problem for both conservation and education at heritage sites. We consider the site of Tarn Hows in the English Lake District National Park, a site which has had significant landscape change over the past 200 years, from developing tree coverage, to the merging of three lakes into one. We created an automated process that combines an elevation map and a vegetation map to build a 3D representation of the landscape. We used this tool to create a 3D Deep Map of Tarn Hows, representing the site's landscape at multiple periods over time, allowing them to be viewed side by side and explored in an interactive environment. This 3D Deep Map provides an exploratory resource for site authorities to educate the public about the historic environment, with embedded multimedia in the application to provide additional information to users that might be disruptive or impractical to display on site. The 3D Deep Map also provides a tool for conservators to plan site maintenance to best maintain the integrity of the historic landscape without negatively impacting visitors' experience of the iconic site.

1. Introduction

Acknowledgement: This research received funding from the Leverhulme Trust (RPG-2015-230), as part of the 'Geospatial Innovation in the Digital Humanities' project. We would also like to thank the National Trust for their engagement in this research.

This article looks at the creation of a 3D Deep Map, focusing on the United Kingdom's National Trust site of Tarn Hows. As part of Lancaster University's 'Geospatial Innovation in the Digital Humanities: A Deep Map of the English Lake District' project, we wanted to develop prototypes beyond existing 2D maps and to explore the concept of a 3D Deep Map and how it could be used to aid in the conservation of a historic site and provide a platform for educating visitors and the general public about the changing histories and landscape of the site [GID18]. We chose to focus on Tarn Hows because it is a major tourist destination in the Lake District National Park, and the site has undergone significant changes to its landscape. For this project, we developed a series of scripts, for the Unity 3D gaming engine, that can take 2D elevation and vegetation maps, and automatically create a 3D visualization. These scripts were used to create the Tarn Hows Deep Map, with an interface for the application that allows for the navigation and comparison between historic periods.

The prototype developed through this study, shows that deep mappings is not confined to 2D mapping applications. Our prototype provides a foundation on which to evaluate deep mapping applications that deviate from the standard 2D map-based application. This research, in cooperation with stakeholders like the National trust, also allows us to explore how the practical application of a 3D deep map can be used in the real world, to engage the public and provide tools for conservation.

2. Background

2.1. Tarn Hows

This project focuses on the National Trust site of Tarn Hows, a mountain lake located in the Lake District National Park. Tarn Hows is one of the most popular sites in the Lake District due to its picturesque scenery and easily accessible walking paths. The site today, is a single lake with an island in the middle, and abundant tree coverage across the site. While the site is known for its beautiful landscape, the site has undergone significant changes over the past 200 years.

In the early 1800s the site of Tarn Hows was comprised of three smaller natural tarns. The site was surrounded by farms and quarries and was used as a common grazing area. In 1862 the site become the property of the Marshall family, who had owned the local farms and quarries. James Garth Marshall endeavored to create a designed landscaped and dammed the stream flowing through the area, which created the single Tarn visible today. Marshall began a planting scheme as well, expanding various tree plantations around the site. Non-native trees were planted around the tarn to increase tree cover in the area. Marshall's landscaping was designed to highlight features within the environment to create a more dramatic landscape [JGM18].

Unfortunately, Marshall died before completing his vision of the site, but by the early 1900s the site was already a popular tourist attraction, mentioned in the writings of travel journals. In 1929,

DOI: 10.2312/gch.20181366

the Marshall family sold the land to Beatrix Potter, the well-known author and artist, who later sold part of the land to the National Trust and left the rest to the Trust in her will [VC-18].

The landscape continued to change over the years, with the tree plantations spreading out into once grassy areas, covering more of the lake's perimeter. Under the ownership of the National trust, footpaths and road access were added between the 1960s and 70s. Efforts were taken to reduce the impact of visitors on the site, including moving car parks to less visible areas. The site remained a major tourist destination in the area, reportedly drawing between a quarter and half a million visitors annually since the 1970s [JGM18].

While the site is well known, and well visited, the changing historic landscapes of the site are difficult to show visitors without adding obstructive signs and plaques that would detract from the natural landscape. The National Trust must consider the modern aesthetic of the site as well as the historic landscapes when planning site maintenance.

2.2. Deep Mapping

This project uses deep mapping as the primary framework for creating an application to represent the changing historic landscapes of Tarn Hows. A deep map is a spatial representation of "the multiple histories of place, the cross-sectional stories of natural and human history [Mah14]." While a traditional map focuses on the depiction of space at a particular time, a deep map focuses on the depiction of place across time [OBR13]. 'Place', in this context, is 'space' with attached meaning, like in the case of this of project, the historic changes to space. With the focus on place, deep maps can be seen a multi-temporal chorography [Roh12].

Deep maps are also intended to be 'open-ended exploration of a particular place' and have an 'emphasis on one particular user interaction: exploration. [RLN13]' An application that allows for this open-ended exploration, creates the potential for an environment where users can relate to the provided meaning attached to place, as well as derive their own from the experience.

Many applications of deep maps discussed in academic papers, have focused on the use of 2D maps with an interactive component. A basic implementation of deep mapping can be seen in one study that focused on exploration as the primary user interaction. This implementation created a Deep Map using Google Maps to display spatial data and a content bar that provides detailed information about visible locations on the map [RLN13].

Another study in deep mapping took a more abstract approach and deviated from the use of a map as the primary interface. This project created a Deep Map using Prezi, creating nonlinear presentation areas, which contained their data. The Prezi application focused on the 'spatial navigation' of the data, by allowing users to move between presentation areas in any order. This allowed for the free exploration of the data, but still allowed for a guided experience with the use of normal Prezi features [OBR13]. This abstract approach shows that deep mapping does not require a map interface to allow for the spatial navigation of data.

Our project aims to explore the loosely defined concept of 'deep mapping' and the merit of 3D representations as a deep map. This research has built prototypes and engaged directly with stakeholders to better understand what a deep map might look like, be engaged with, and how it might be used in the real world. We are working with the National Trust to determine the effectiveness of this application as a tool for educational dissemination and conservation.

3. Methodology

3.1. Basic Terminology

This project uses the Unity 3D gaming engine [UNI18], which allows for building of an easily navigable 3D world. One of the key components to the 3D world in Unity is a Terrain. A Terrain is a plane object in the 3D space that is used as the ground. This plane is defined by a grid, with no data it is a flat object, and the changing of various values for each square in the grid creates the virtual landscape. Each grid square can be assigned values for attributes such as height and color. Changing the colors of the Terrain is referred to as painting. Objects, like trees and grass, can also be assigned to each square. Some of the assigned objects can be 3D, like trees in the foreground, while others can be Billboards, which is a flat plane with a cut out image of the assigned feature. A billboard is used for elements like grass, or trees in the distance, and are intended to reduce the processing power required by the gaming engine for elements that do not need detail of a fully 3D object.

The scripts designed for this project use maps as inputs to perform their specific operation. These maps are Raster images, which is essentially a grid, where each square in the grid is a single pixel in the image and each pixel has a value that determines its color. The use of Raster images makes it relatively straight forward to bring the color data from the maps into Unity and assign those values to attributes in the Terrain grid.

3.2. Scripts

A series of scripts were designed for the gaming engine Unity 3D, that could automatically build a 3D environment. Three scripts were made, the first was designed to create the topography of a terrain based on a 2D elevation map. The elevation script takes a traditional grayscale elevation map and uses the color value for each pixel on the map as the height value for the corresponding grid square on the terrain.

The second script focuses on generating the minor features of the landscape. This script takes a 2D vegetation map, which is used to paint the terrain and create small details like grass. When a vegetation map is loaded into the interface for this script, the user is able to assign each color of the image to a different environmental detail they have added to the game engine. For instance, a user could assign the green pixels of the map to be grasslands, which could add a grass texture to the corresponding area on the terrain and add grass billboard objects to the area as well.

The third script is designed to generate tree cover. Like the second script, this one uses the same vegetation map as its input. The interface for this script allows the user to assigned whether each color on the map should have trees, assign which trees should be

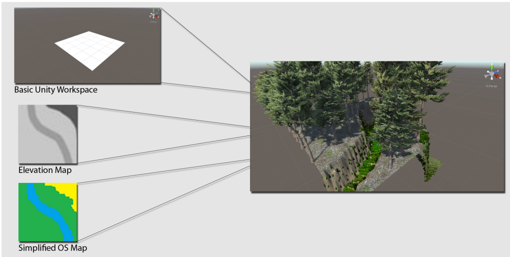

Figure 1: *Figure of the automated process. The combination of a 3D environment, vegetation map, and elevation map, result in a new 3D environment.*

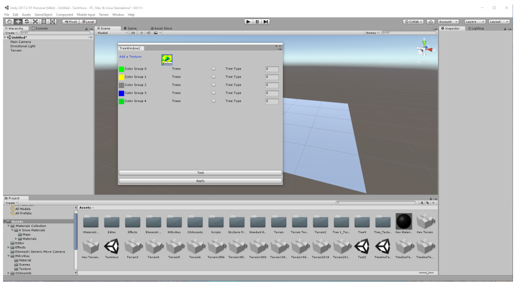

Figure 2: *View of script interface, allowing for the selection of terrain attributes based on color.*

assigned to each color that trees are allowed. The script randomly places trees in assigned areas of the terrain, using an algorithm that spaces the trees based on a user specified distance range, ensuring that trees do not appear too clumped together, or too far apart. This placement algorithm allows for a more natural looking tree cover and allows for control on the density of trees, to more accurately represent the real world landscape.

3.3. Tarn Hows Deep Map

To visualize the multiple historic landscapes of Tarn Hows, we compiled elevation and vegetation maps for three time periods of the site, 1856, 1900, and 2018. We started with 2018, building an elevation map from LIDAR data available from the Government Digital Service [DAT18], and augmented by satellite elevation data for parts not covered by LIDAR survey. LIDAR data was used because it has a high resolution, about one meter, as compared to standard satellite data. The vegetation map for 2018 was based on satellite imagery.

The 2018 elevation map was used for the 1900 time period, as the site was a single Tarn, as it is today. The 1900 vegetation map was made using data from the Ordinance Survey (OS) map of the time period. While not as detailed as a satellite image, the OS map depicts where the various tree plantations were as well as the profile of the Tarn.

The 1856 vegetation map was also based on OS data, the 1856 OS map being the first to cover the area of Tarn Hows. This time period was before the merger of the three Tarns, and the OS map depicts the original Tarns. The 2018 elevation map was modified for this period using the limited elevation data and Tarn profiles available in the OS map.

With the elevation and vegetation maps prepared, we used the Unity scripts to automatically generate an environment for each period. We then built an interface that allows users to switch between time periods. The interface gives users the option of using one camera, to explore the site freely using traditional gaming interaction, or two cameras, to view two time periods side be side. When using the two camera view, the cameras are synced, so any movement by the user is reflected in both views, allowing users to explore the landscape in multiple periods at the same time. A separate timeline slider for each camera permits the user to change and compare time periods at will.

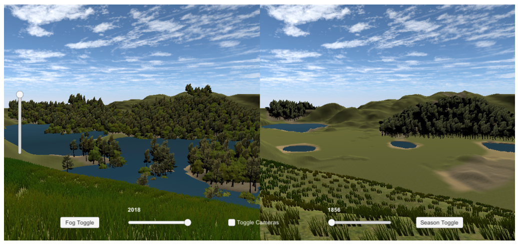

Figure 3: *View with two cameras, showing 2018(left) and 1856(right)*

The interface also includes the ability to change seasons in the landscape, which is done by switching out assets, the trees, grasses and paint textures, to reflect the desired season. Another slider in the interface gives users the option of changing the sky and the lighting level in the environment, and a toggle button allows for the addition of fog effects. These features provide enhanced realism to the virtual environment that could allow for more meaningful engagement with the application.

As this application is built in the Unity game engine, any number of multimedia can be added to the environment in order to enhance the user's engagement. As an example, we added a sign which explains a little about the site, that users can read as they overlook the lake. This type of media placement is important because it provides a means of disseminating interpretive data that can't be placed in the real-world environment without detracting from the natural beauty of the site.

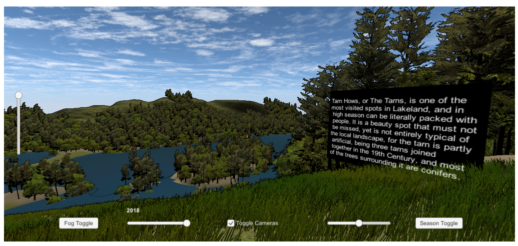

Figure 4: *View overlooking the Tarn with embedded text description*

4. Discussion

The Tarn Hows Deep Map application that we created provides a tool for both education and public interaction, as well a means of site conservation and management. This application can be used as a platform for educating the public about the layer history of the site. With embedded multi media and the functionality to move between time periods, the deep map provides a means of 'layered storytelling' and allows for the open-ended exploration of the place.

For site authorities, this application can help visualize past environments to inform site maintenance, and visualize the future landscape based on planned changes. With sites that have had a rich history of landscape change it can be difficult for authorities to plan maintenance of the site. In the case of Tarn Hows, the modern environment is an iconic tourist destination, but today's landscape differs significantly from the past. Authorities must determine what trees can be cut back to better reflect the historic plantations of the Marshall family, while not removing too much that might negatively affect the picturesque views and visitors' engagement with the natural landscape. The Deep Map also provides a means to visualize future plans for the site, allowing authorities to gain feedback on proposed changes without having to modify the real-world landscape first.

The automatic generation of a landscape, by the scripts written for this project, provides the means to quickly create visualizations of modern and historic environments. While there is an issue of accuracy, such as individual trees do not necessarily reflect the positions of their real-world counterparts, this method allows for the creation of an environment, even with limited data.

5. Conclusion

This project has allowed us to create a tool for quickly visualizing the past, generating an engaging, interactive and exploratory interface. The tool provides a means of educating users about the multiple histories of a site, in addition to providing a tool that site authorities and other organizations can use to visualize modern and historic landscapes. This application shows that a 3D Deep Map delivers an explorable visualization and can represent the multiple histories of a place in an engaging way. Our research demonstrates the viability of deep mapping in a 3D application and provides a base for evaluating deep mapping applications that diverge from the typical 2D map interface. In the future we will be working with site authorities to use this tool to aid in the conservation of Tarn Hows and other sites and create educational exhibits to help disseminate historic data to the public. The Unity scripts designed for this project will be available to download from our GitHub repository https://github.com/alex1200/DeepmapScripts.

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