

Towards 3D Scholarly Editions: The Battle of Mount Street Bridge

Costas Papadopoulos <k_dot_papadopoulos_at_maastrichtuniversity_dot_nl>, Maastricht University

Susan Schreibman <s_dot_schreibman_at_maastrichtuniversity_dot_nl>, Maastricht University

Abstract

This paper explores different ways of modelling and simulating complex spatial and temporal events, such as battles, for which it has been practically impossible to (re)construct the thousands if not hundreds of thousands of variables of which they are comprised. This research utilises as a case study the Battle of Mount Street Bridge of the Irish Easter 1916 Rising, in which the number of British casualties has been fiercely debated. The research is framed within the theory and practice of digital scholarly editions, which provides a new paradigm for approaching virtual worlds in a contextualized and annotated environment. This paper also discusses the challenges of creating virtual worlds for online environments in which there is rapid obsolescence of software and platforms and an absence of standards.

1. INTRODUCTION

In the last three decades, cultural heritage, history, and archaeology have made use of three-dimensional digital (re)constructions as tools in the process of knowledge production by making complex two-dimensional data more comprehensible and by simulating spatial and temporal aspects of the past that could not be addressed by using conventional methods. Despite the precariousness of working with 3D technologies in which research projects are reliant on software, hardware, operating systems, and the Internet itself that constantly change, we argue here that the benefits of translating physical environments into three-dimensional models - both the process of modelling as well as the models themselves - outweigh the problems caused by the medium.

Contested Memories: The Battle of Mount Street Bridge project focuses on a battle that took place on Wednesday, 26th April 1916 during the week of the Easter uprising in Dublin. This battle, between a small group of Irish rebels and a much larger force that the British high command sent to Dublin to put down the rebellion, was used to investigate to what extent a virtual world can enable alternative forms of research, help in the interpretive process, and assist knowledge production for both general audiences and specialists. More specifically, it explores how 3D (re)constructions can augment and enrich the palette of methodologies that we use to answer traditional historical questions by enhancing our ability to understand and interpret space as well as to map temporal dimensions within that space. In seeking to map both time and space, we encountered a common problem reported in 3D scholarship; that is the depiction of time in a meaningful way that complements the spatial dimension and enhances the perception of the virtual world [Zuk et al. 2005] [Stefani et al. 2008] [Laycock et al. 2008].

This paper will discuss the decision-making process of gathering and interpreting primary sources for the construction of a virtual world, issues of 3D modelling and representation, the challenges that the project faced, and its future directions. It will also problematise the term “virtual world” by referring to previous and current examples in heritage studies, also proposing a typology based on their use in teaching, research, and dissemination. It will argue that the process of (re)construction is a valuable tool that provides opportunities for experimentation and new insights, enabling specialists to better comprehend the multidimensional and ambiguous character of historical settings and events. Finally, by drawing from the theory and practice of Digital Scholarly Editions, this paper will suggest that 3D (re)construction projects can become knowledge sites in which the models are seen as text, and documentary evidence

in the form of apparatus provides an enriched understanding of its content, thus giving credit and value to the products of 3D modelling as scholarship.

2. HISTORICAL VIRTUAL WORLDS: THE CHALLENGES OF THE STATE-OF-THE-ART

In more than three decades of 3D heritage visualisation and simulation there have been immense technological advancements in both hardware and software, which have also driven the development of theoretical and methodological approaches, processes, and products; from the first schematic representations of buildings (see [Reilly 2016]) to photorealistic renderings and predictive simulations of ancient structures (see [Dawson et al. 2007]); and from spatial analysis (see [Paliou et al. 2011]) and physics simulations (see [Oetelaar 2016]) to interactive virtual worlds utilising online platforms (see [Sequiera and Morgado 2013]) and game engines (see the projects carried out as part of the Humanities Virtual Worlds Consortium – <http://virtualworlds.etc.ucla.edu/>).

In the last ten years, there have been several definitions for virtual worlds primarily reflecting Second Life and multiplayer game approaches; from Bell's (2008) "synchronous, persistent network of people, represented as avatars, facilitated by networked computers" to Schroeder's (2008) "persistent virtual environments in which people experience others as being there with them – and where they can interact with them". Girvan (2013) defines a virtual world as a "persistent, simulated, and immersive environment facilitated by networked computers, providing multiple users with avatars and communication tools with which to act and interact in world and in real time". Nevelsteen (2017) on the other hand describes a virtual world as a "simulated environment where MANY agents can virtually interact with each other, act and react to things, phenomena and the environment; agents can be ZERO or MANY human(s), each represented by MANYII entities called a virtual self (an avatar), or MANY software agents; all action/reaction/interaction must happen in a real-time shared spatiotemporal nonpausable virtual environment; the environment may consist of many data spaces, but the collection of data spaces should constitute a shared data space, ONE persistent shard". Trying to map these definitions to historical virtual worlds becomes futile, since the vast majority do not fulfil the necessary conditions to be classified as virtual worlds: avatars, multiple users and in-world interaction, real-time, persistency, communication tools, to name a few. Also, these definitions neglect more recent approaches in which such environments become tools in research and education. For this reason, we might either abandon the term and continue using the more generic terminology that is typically used interchangeably in such contexts, such as 3D visualisations, computer graphic simulations, and digital (re)constructions, or reconceive the definition of virtual worlds so that they can better encompass the historical environments created and their role and value in the process of knowledge production.

An abundance of virtual world projects in archaeology, history, and heritage-related subjects have been created, especially since the 2000s, particularly during the years that Second Life and Open Simulator were at their peak. Both platforms, and especially Open Simulator which is the free and open-source alternative to Second Life, democratised the process of creating virtual worlds as they did not require highly advanced 3D modelling skills. These online environments enabled a novel way of experiencing history/heritage and working in an online environment for pedagogical and research purposes unlike anything previously available [Wankel and Kingsley 2009].

Second Life, as the name suggests, attempts to immerse its users in a world that has its own social and cultural systems, industry, and currency, while "residents" in order to build and maintain their second lives have to buy or rent a piece of land on the "grid". In the early years of Second Life, many educational institutions and projects purchased mainland regions or islands to build hubs that would enable new ways of online teaching, collaboration, and knowledge creation. However, due to the policy of Linden Labs to discontinue educational pricing, Second Life became unaffordable for many research groups and institutions. As a result, and due to the way that these virtual worlds functioned, e.g. in-world created 3D models and modalities of communication that could not be exported, most of these worlds have now vanished [McDonough et al. 2010, 89–97]. One of the most characteristic examples of this was the Okapi (Open Knowledge and the Public Interest) island built by the University of California Berkeley to create an online collaborative environment based on the excavation of Çatalhöyük, a Neolithic site in Anatolia, Turkey [Morgan 2009]. Okapi island gained international media exposure and virtual learning awards, and soon became an exemplar of how such virtual worlds could function for educational and research purposes. However, due to the exigencies of the

platform, Okapi island ceased to exist in February 2012. Several other projects developed in Second Life, such as the Virtual Rosewood [González-Tennant 2013] and Theatron [Beacham 2009] are no longer accessible since the platform's maintenance costs were prohibitive for the research teams.

Despite the profound benefits of platforms, such as Second Life, it was the advent of Unity Technologies that boosted the production of heritage virtual worlds since they enabled the creation of highly-detailed models, the embedding of features found in game engines, such as real-time physics and lighting effects, while allowing in-browser experiences without the need to download additional software. They also allowed modellers to reuse their content created in specialised computer graphics packages, thus not requiring in-world modelling or the translation/modification of existing models. However, similar to the problems in Second Life, online virtual worlds developed in the game engine, Unity 3D, recently ceased to exist due to the Netscape Plugin Application Programming Interface (NPAPI) that was phased out by browsers in the period 2014-2017. The NPAPI is a technology that allows third party software developers to produce plugins and web extensions that can run software as a layer within html pages on internet browsers (e.g. Oracle's Java plugin, Adobe Flash, and Apple Quicktime web extensions). Since these plugins became increasingly vulnerable to security flaws, browser manufacturers decided to replace the plugin functionality with HTML5 compliant approaches.

Considering that virtual worlds developed in Second Life or Unity 3D were intended to be available online, it is striking that at the time of writing this paper only a handful are still accessible. Contrary to the video game community that often builds emulators to overcome – even temporarily – problems of access [Kraus and Donahue 2012], heritage virtual worlds cannot cope with such demands. Many first generation projects are inaccessible and thus it is difficult for new projects to learn from previous work, especially when the experiential three-dimensional approach to space and time is only accessible via conventional, static, two-dimensional images. Therefore, the vast majority of the-state-of-the-art - at least in its original format - is lost. Online and interactive scholarship, even text-based, has always faced technological shifts and exigencies; however, even in such a fragile ecosystem, changes, successes, and failures enable alternative forms of research, inform the interpretive process, and assist knowledge production.

In the following paragraphs, we will refer to previous and current heritage virtual worlds projects dividing them into three broadly defined categories: Virtual Museums; Research Laboratories; and Teaching Environments, taking into account the features of each environment, intended purposes, as well as use by different audiences.^[1] Standalone, offline, 3D modelling projects have a much longer history than online environments and could also be categorised under the proposed typology as they were created to fulfil different purposes and for different audiences. However, given that these were not intended to be publicly available and were created to fulfill different goals, we will only refer here to online virtual worlds.^[2]

"Virtual Museums" are environments that represent buildings, cityscapes, or landscapes at a moment of their existence or through time, allowing user navigation either using avatars or a first person view. We use the word "museum" since these environments are experienced in a similar way to museum exhibits; users can move around and observe the artefacts but cannot interact with, manipulate, or modify them. Such virtual worlds include little or no contextual information in-world, whereas contextual and interpretative material may be supplied in the form of accompanying online resources, e.g. website, or conventional publications. By definition, most virtual world projects fall under the "Virtual Museums" category since the minimum condition that has to be fulfilled is a 3D model accessible online. For example, the Zamani project (<http://www.zamaniproject.org/>) has recorded highly-detailed and metrically accurate 3D models of Africa's heritage sites that – among others – can be explored using the Unity Web player. Similarly, the Virtual Rosewood Research project (<http://www.rosewood-heritage.net/>) that focuses on Rosewood, Florida, an African American town destroyed during the 1923 race riot ([González-Tennant 2015]; also see [González-Tennant 2013] for previous reconstructions of Rosewood on Second Life), and Virtual Williamsburg 1776 ([Fischer 2011]; <http://research.history.org/vw1776/>), have made use of Unity to make these available online. Zamani, Rosewood, and Williamsburg projects are only comprised of 3D models and do not include any supplementary material in-world. Information that contextualises and provides additional information on these projects, including background, decision-making, and 3D modelling, is included on the websites that host the virtual worlds and in the referenced publications.

"Research Laboratories" on the other hand, do not only enable users, primarily researchers, to experience

(re)constructions of and gain knowledge about past places, periods, and events but also provide them with experimentation opportunities by permitting the alteration of variables, thus allowing testing of hypotheses, new approaches to old data and research questions, and the construction of new narratives. These processes stimulate discussion and produce creative responses, thus having a transformative impact on historical sense-making, reasoning, and understanding. Therefore, virtual worlds become synonymous with knowledge production and the research process that leads to their creation, i.e. problematising sources, identifying variables, and justifying solutions, opens a dialogue that can generate new avenues of scholarship unlike traditional spatiotemporal approaches. For example, the Digital Hadrian's Villa project [Frischer et al. 2016], whose online version is implemented in Unity (not currently active), allows users to test archaeoastronomical theories, including the alignment of the sun with the tower of Roccabruna, in the summer solstices during Hadrian's reign to discover celestial arrangements in the night sky as these would have been seen in the past (for a similar example on WebGL – currently active – see the Virtual Meridian of Augustus, <http://cgi.soic.indiana.edu/~vwhl/VirtualMeridian/WebGL/index.html>; also see [Frischer et al. 2017]). Similar attempts using the Virtual Reality Modelling Language (VRML) to create interactive visualisations with parameters that can be changed to demonstrate possibilities and variations in digital (re)constructions have been implemented since the early days of computer graphics (see for example [Roberts and Ryan 1997]'s work on a Roman theatre in Canterbury). This category is the one with the fewest examples since there is no off-the-shelf platform that supports the interactive elements of such worlds as it requires many more resources in comparison to Virtual Museum projects since interactions have to be designed and pre-programmed by specialists with subject expertise and often to be enabled by Artificial Intelligence mechanisms (see for example [Vosinakis and Avranidis 2016]).

In the “Teaching Environments” category, virtual worlds act as fora of communication, discussion, and outreach. It is not only about the virtual worlds themselves but also about how such worlds are used as a basis for teaching different groups and stakeholders, enquiry, synthesis, and critical analysis. Although there are a few cases where virtual classes are held within virtual worlds in which users can collectively attend teaching sessions and interact with each other and the instructor(s), as well as virtual worlds that were adapted to be used as teaching material (see for example [Earle et al. 2011]; [Earle and Hales 2009] on the Crystal Palace Project – VW is inactive: <http://slurl.com/seconde-life/Sydenham%20Crystal%20Palace/158/201/23>); this category primarily includes virtual worlds built to provide an embodied and sensorial understanding and an immersive experience of a period, culture, or historical event by employing a narrative that guides users in their experience of the virtual world. For example, Oxford’s First World War Second Life project (still active: <http://maps.secondlife.com/secondlife/Frideswide/219/199/646/>) that combines areas of the Western Front (1914-18) and digitised poetry from the First World War Poetry Digital Archive (<https://www.oucs.ox.ac.uk/ww1lit/>), allows visitors to experience the poetry of the Great War in an evocative and emotive visualisation of the Western Front by providing access to archival material, such as veteran interviews, video clips, readings of poems, and manuscripts. In this category we also include novel approaches to teaching and learning that promote enquiry, teamwork, effective participation, self-management, reflective learning, and creative thinking, such as Okapi Island’s Machinima: The Hunt, a film made by students and faculty exclusively within the virtual world (<https://youtu.be/n86eZOr-9xE>), portraying hunting and burial ceremonies in everyday life at Çatalhöyük.

While the typologies of 3D scholarship outlined above make the models of use to a wider audience, they do not provide an integrated environment that brings to the fore the decision making process, for example by making available the materials collected that informed the research behind or steps taken to create the models so others - beyond the research team - can utilise the knowledge developed during the modelling process. As a result, this scholarship exists in a trifurcated information space; the original models are available to the individual or the team who worked on them, a version of the models - often downgraded - exists electronically (if technology allows), while the materials that informed decisions and the knowledge generated from them is written about in conventional publication formats or never become available beyond the research team. To overcome this, we are proposing a fourth, still relatively nascent typology, that of 3D Scholarly Editions. 3D DSEs are knowledge sites that provide hermeneutic richness [Champion 2015] that takes advantage of the interactivity of the medium and enables the communication of the process and results of that scholarship within a single spatiotemporal, immersive, and sensory environment.

The typologies explored here are offered as ways of creating broad categories for 3D (re)presentations in order to begin

to develop, not only a shared vocabulary for discussing virtual worlds as knowledge production, but to begin to theorise this type of scholarship, not in terms of best practice but in terms of more consistency with other digital scholarship, including research goals, audiences addressed, methodologies and standards, and features that can be expected from each type of virtual world.

In the research trajectory of the Battle of Mount Street Bridge project, the 3D environment was one of several tools and resources that formed a Research Laboratory (per the typology enumerated above). Analogue and digital resources, spreadsheets and models, along with excursions to the battle site were utilised to build an increasingly nuanced and complex understanding of the battle. Once the article was published that explored our research findings [Hughes et al. 2017] we became dissatisfied that outside of our project team, the wider community interested in the battle could not access, evaluate, and reuse our decision-making process, nor could it use the 3D environment to posit alternative theories; hence our investigation of a fourth model, that of a Digital Scholarly Edition (DSE).

3. TOWARDS 3D SCHOLARLY EDITIONS

3D DSEs are 3D (re)constructions which include robust contextual information, metadata, and paradata either in the form of in-world annotations or supplementary side sources. In both cases the contextual information or annotation can be text or multimodal. Indeed, we would argue that the annotation needs to take advantage of the affordances of the medium to be truly effective in providing access to the creation process, background information about the world being modelled, and alternative versions of the (re)construction. This type draws from the theory and practice of Digital Scholarly Editing (DSE) which derives from a long history of practice in editing texts for print (See [Shillingsburg 1996]; [Apollon et al. 2014]; [Schreibman 2013]; [Pierazzo 2015]; [Driscoll and Pierazzo 2016]).

The digital has provided textual scholars with a wide palette with which to remediate, not only the textual record (from grave inscriptions to manuscripts of modernist texts to multiple editions of a work in print), but increasingly other mediums of knowledge transmission (e.g. images, audio recordings, maps), recording, (re)creating, and describing a wide variety of linguistic and non-linguistic features (verbal, visual, oral, and numeric). Textual scholarship includes not only the transmission of texts, but the social processes of their transmission [McKenzie 1999, 13]. Thus a 3D scholarly edition should not be thought of as a defined object, but a methodological field in which a set of codes, not only the technological codes that govern the creation of the world, but the social, theoretical, and historical codes that its makers adopt in its creation, impose a prefiguring frame on the reality being created [Barthes 1977].

The construction of such an edition entails building an intertextual network composed of the primary text (in this case the 3D model) along with its accompanying annotation and apparatus providing a base from which the reader can actively engage in the knowledge creation process. Embedding the iconography of virtual worlds into what we might broadly describe as scholarly editing practice, opens up new vistas for scholarship and communicating the results of that scholarship within spatiotemporal environments that are immersive and multisensorial [Schreibman and Papadopoulos 2019]. If the goal of the modelled world is to create its own ecosystem to provoke and encourage evolving thought about the material, aesthetic, and cultures of the real-world events it simulates [Schreibman 2013], at the heart of this ecosystem is the text, the modelled world.

All edited texts are, at their core, dialogues [Driscoll and Pierazzo 2016, xiv]. Dialogues between the text and the editor and between the edited text and its readers. Scholarly editions are fundamentally, fabrications. They (re)present a work (or in the case of 3D, a world) as it never existed historically,^[3] but in its (re)presentation, providing greater access to readers, not only to the textual record, but to the social, historical, and economic factors which led to its creation and subsequent use. This surrounding material, referred to as apparatus is annotative, providing critical, textual, and biographical notes. This can be seen in an online edition such as The Chymistry of Isaac Newton ([Newman 2016]; <http://webapp1.dlib.indiana.edu/newton/>) that provides both diplomatic and normalised (modernised) transcriptions, alongside online tools, such as glossaries, indexes, and a guide to the symbols Newton used, so that the reader can better interpret the text. Depending on the theory with which the editor produces the text (typically described in the introductory material), the annotation, as well as edited text itself, follows standard editorial practices.^[4]

16

17

18

19

20

Digital Scholarly Editions (as opposed to editions edited for print) have opened up new modalities for annotation to include, in addition to text, audio, video, images, and data linked from other sources. An example of this is The Walt Whitman Archive ([Folsom and Price 2017]; <http://whitmanarchive.org/>) that publishes Whitman's published work alongside manuscripts (in both image and transcription formats), coupled with commentary, translations, audio recordings, and bibliographic information. In the case of 3D (re)constructions, annotation might include in-world sampling of sound in different sections of a renaissance church based on the position of the user in the virtual world, mechanisms to present alternative structural models according to written evidence and parallel sources, or a video in which a person describes some aspect of the text. We are calling these features annotations because, unlike the testing amongst multiple variables that users can undertake in "Research Laboratories", their goal is to explicate as opposed to test. For example, the 3D (re)constructions may offer one version of a building; however, evidence that supports alternative versions of certain architectural features may be represented by other models accessible in-world through a pop-up box or by replacing the current version of a feature with other possible versions; areas of uncertainty may be rendered in different colours and shading to indicate hypotheses, sources, and surviving evidence; or, ambiguous features may be toggled on and off or replaced by alternative versions, also indicating how other elements will be affected by these changes (e.g. a larger door opening may indicate a lighter roof structure). Although such approaches in the creation of digital (re)constructions, especially in archaeological contexts, have been presented since the early years of the application of computer graphics in the field (see for example [Roberts and Ryan 1997]; [Strothotte et al. 1999]; [Eiteljorg 2000]; [Djurcic et al. 2001]; [Fischer and Stinson 2003]; [Niccolucci and Hermon 2002]; [Pollini et al. 2005]; [Kensek 2007]; [Papadopoulos and Earl 2009]), we believe that they haven't been adequately supported by theoretical and methodological frameworks. In this paper we argue that following the paradigm of digital scholarly editions, the processes and results of digital (re)constructions for heritage datasets can be further informed, thus creating a more robust framework for considering 3D models and modelling as scholarship (also see [Schreibman and Papadopoulos 2019]).

Several virtual world projects have followed the paradigm of what we call 3D Scholarly Editions, providing contextual information, including metadata and paradata, in the form of in-world textual and multimedia annotations, and/or supplementary side sources. For example, the Virtual Middletown Living Museum Project (<http://idialab.org/virtual-middletown-living-museum-in-blue-mars/>) currently under development by IDIA Lab at Ball State University, which explores life in Muncie, Indiana in 1920-30s based on the seminal Middletown Studies by Robert and Helen Lynd, includes for the virtual world of the Ball Glass Factory, in-world interactive multimedia annotations to re-enact and inform visitors about the working life in a factory of the period.^[5] Similarly, the Social Justice History Platform (originally built in Unity 3D^[6] as part of The Soweto Historical GIS Project; <http://www.dhinitiative.org/projects/shgis>) brings together spatial, temporal, and geographic data, archival material, and multimedia for Soweto under the South African apartheid regimes. Lastly, we should highlight VSIm, the only off-the-shelf platform to date that was developed in an attempt to respond to the criticisms about the transparency of 3D modelling as a process and the concerns over the establishment of 3D as an accepted modality of scholarship by embedding annotations and links to sources, crafting narratives, and building arguments within the 3D models [Snyder 2014] [Sullivan and Snyder 2017]. Some of the features supported in VSIm are similar to those we describe for 3D Editions (e.g. textual annotations).

However, we believe that 3D scholarship could afford more dynamic and interactive annotative features that go beyond conventional textual and multimedia paradigms as outlined above.^[7] Contested Memories: The Battle of Mount Street Bridge Virtual World (<https://mountstreet1916.ie/>) has been experimenting with such an environment.

4. CONTESTED MEMORIES: AN INTRODUCTION TO THE BATTLE OF MOUNT STREET BRIDGE PROJECT

Contested Memories: The Battle of Mount Street Bridge (BMSB) project began in 2013 as part of the Humanities Virtual World Consortium (HVWC) (<http://virtualworlds.etc.ucla.edu/>), funded by the Andrew W. Mellon Foundation. The HVWC planning grant was funded in 2010 at what was arguably the height of academic interest in virtual worlds. Despite the excitement of the affordances of the technology, there was a growing awareness that for virtual worlds to flourish in heritage and academic settings, an alternative platform was necessary that allowed institutions greater control over their

assets along with a security of tenure. As can be seen from section two, the final blow to many of the projects constructed in Second Life was the 2012 pricing structure which caused the vast majority of projects to abandon their assets and their lands.

The HVWC sought to intervene by exploring how online and interactive virtual worlds that provide tools and methods to approach space and time in three dimensions can enable collaborative networked approaches to cultural heritage, transform scholarly communication, evoke sensorial experience, and advance research practices in the humanities. These goals were in line with the definitions of virtual worlds referenced above by Bell, Schroeder, Girvan, and Nevelsteen, with the added ambition of advancing research practice in the humanities to provide a broader palette for researchers to ask and answer research questions in which the phenomenology of time and space could not be addressed using conventional (including more traditional digital) methods. In order to fulfil the aims of the Consortium, four projects were developed that covered a range of disciplines, including ancient and modern history, architecture, archaeology, and Tibetan studies, and a time frame from the Roman period to the early 20th century. The other projects of HVWC included RomeLab, led by Chris Johanson (UCLA); Lhasa, led by David Germano, Kurtis Schaeffer, and Tsering Gyalpo (University of Virginia); and, Hadrian's Villa, led by Bernard Fischer (University of Indiana and John Fillwalk in the IDIA Lab of Ball State University). At the time, Unity 3D was selected as the platform to host the four virtual worlds. Although Unity 3D is a closed-source game development engine, it supported, contrary to other platforms evaluated in the planning stage of the grant (Second Life and OpenSimulator), highly detailed models and most features found in game engines, including real-time physics, lighting effects, and the ability to modify the Graphic User Interface. Unity would also allow tailoring the front-end to accommodate the four diverse projects and would support networked research and learning. Most of all, using a platform that seemed to emerge as the standard for virtual worlds would allow the partners to focus on scholarly content rather than dealing with technical challenges.

25

5. THE BATTLE OF MOUNT STREET BRIDGE: A BRIEF HISTORICAL BACKGROUND

The Easter Rising of 1916 is considered the single most important event in the fight for Irish independence from Great Britain. It began on Easter Monday, 24th April, with Patrick Pearse, the leader of the Rising, declaring an Irish Republic on the steps of the General Post Office in Dublin's city centre. Within minutes, the British were telegraphed about the insurrection and the following day began mobilising troops who were training in England for the open fields of the Western Front. In less than a week the rebels had been defeated and rounded up. By 12th May, 14 leaders had been executed. Although the Rising might be considered a failure militarily, it set the wheels in motion for Irish independence which was achieved in 1921.

26

The Irish (known as the Volunteers) took a number of key locations around Dublin on Monday afternoon, forming, in effect, a perimeter ring around the city centre, blocking the major routes of entry. One of the most important of these locations was to the south where the port of Kingstown (now Dún Laoghaire) is located. The 3rd Battalion of the Irish Volunteers took over Boland's Mill on Grand Canal Dock on one of the southern routes into the city centre under the command of Éamon De Valera. It was from this location that the command of south inner city was to take place. A small detachment – 14 men – under the command of Lieutenant Michael Malone – occupied four buildings to the west of Boland Mills: 25 Northumberland Road, St. Stephen's Schoolhouse, St. Stephen's Parochial Hall, and Clanwilliam House in and around Northumberland Road. In effect, this blocked the coast road route to the city centre via Mount Street Bridge. Three additional men under the direct command of de Valera, were stationed on the rooftop of Robert's Builders yard (Figure 1).

27

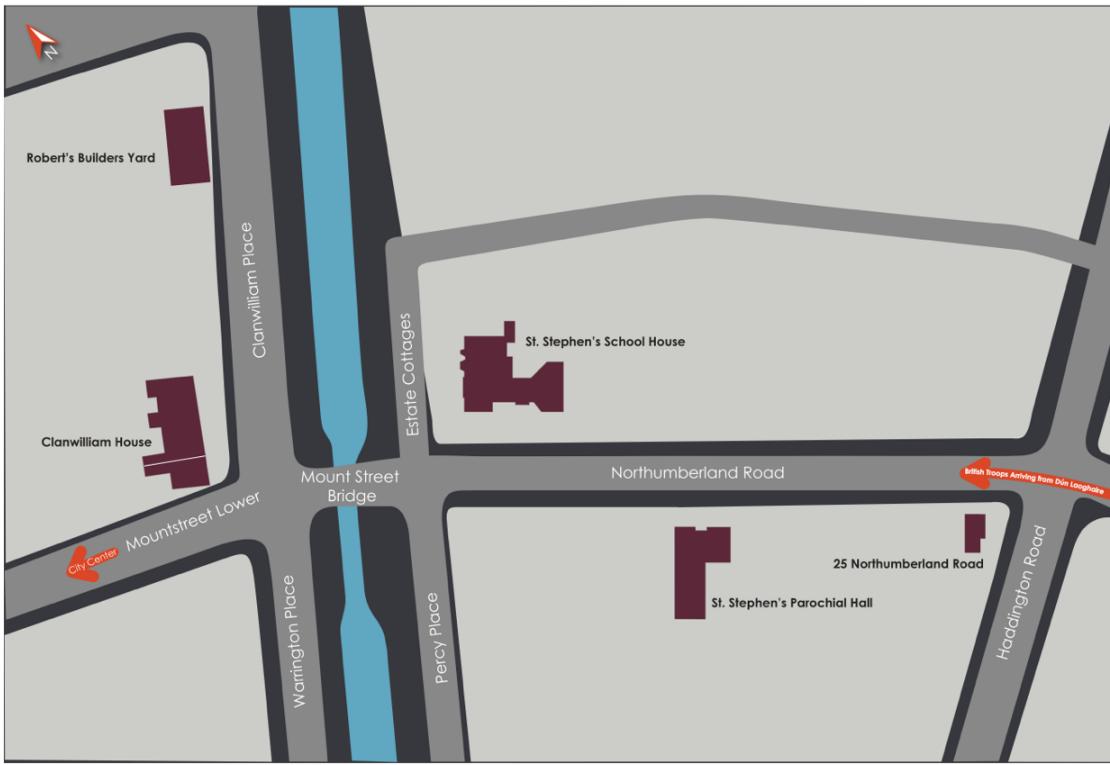


Figure 1. A schematic map of the battlefield and the five building occupied by 17 Irish Volunteers. The British troops arrived from the south (from the direction of Dun Laoghaire) and first came under gunfire from 25 Northumberland Road.

On Monday afternoon British authorities began mobilising troops in England to reinforce the forces already in Ireland, many of them in training. On Tuesday evening, two battalions — the 2/7th and 2/8th — popularly known as the Sherwood Foresters sailed on a night boat from Liverpool to Kingstown. On Wednesday morning around 11.00 a.m. 26 April, some 1750 men marched up the coast road towards the city centre. At around 12.30 p.m. the forward company, Company C of the 2/7th met stiff resistance from 25 Northumberland Road where Malone and James Grace opened fire into the oncoming troops as they approached the junction. The first casualties included Captain Frederick Christian Dietrichsen and 2nd Lieutenant William Victor Hawken as they were easily distinguished from the other ranks as only officers carried pistols (regular troops were issued with rifles). 28

The battle raged well into the evening, with detachments of British troops making their way North on Northumberland Road, being met with gunfire, first from the four men in Parochial Hall, then shortly afterwards by fire from the eight Volunteers in Clanwilliam House. Other detachments made left and right flanking actions attempting to find alternative routes by which to take Mount Street Bridge. Troops that took the right flank found themselves under fire as they approached the canal from Robert's Builders Yards, and those that approached from the left were fired upon by the Volunteers in Clanwilliam House (Figure 2). Eventually, the sheer numbers of the British troops, coupled with their superior firepower, allowed them to take the occupied buildings: 25 Northumberland Road fell first, with Malone killed and Grace escaping from the back of the house; the men in Parochial Hall ran out of ammo and escaped into the back garden; the British spent significant time in taking the School House, only to find it empty (it had been abandoned by the Volunteers Tuesday as being a poor position); Clanwilliam House was the last of the Volunteer posts to fall following a concerted rush by troops from the 2/8th and 2/7th Sherwood Foresters during which the house caught fire after successive bombing by the British: three of the eight men inside died (see [Hughes et al. 2017] for a more thorough description of the battle). 29

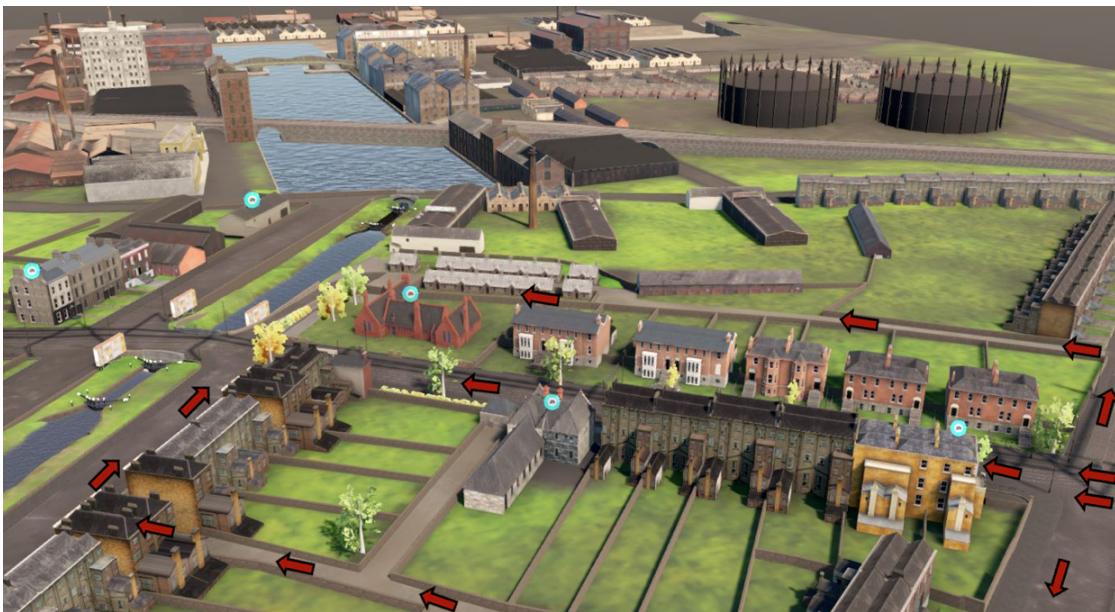


Figure 2. Aerial View of the 3D modelled Battlefield. Red arrows indicate the routes that the British troops followed.

Militarily and in terms of casualties inflicted, the battle at Mount Street Bridge was the most successful Irish engagement of the Rising and accounted for a significant proportion of British casualties. And although the Rising has been the subject of a vast and growing historiography, there remained a number of significant questions surrounding this battle. Among the most contested is the extent of the casualties suffered by the British; the rebel casualties are clear – four of the volunteers were killed. Most commonly, historians have cited the figure produced for British casualties provided by General Sir John Maxwell (appointed general officer commanding in chief the forces in Ireland after the outbreak of the Rising) in a report compiled shortly after the event in May 1916: 234 casualties. “4 officers were killed, 14 wounded, and of Other Ranks 216 were killed and wounded” (The National Archives, WO 32/9523 Maxwell to French, 25 Apr. 1916). These figures are usually reproduced uncritically but are problematic. For one, they contrast significantly with other British sources produced at the time and afterwards that offer casualty figures ranging from 155 to 196 (see [Hughes et al. 2017]).

Given the potential range of figures, and the almost propagandistic nature of some of the writing on the battle itself, it was felt that this event lent itself to the types of methods outlined in this paper to create a more realistic narrative around the events on Mount Street. Moreover, this battle is of additional interest as it is one of the first that widely documents fighting in a built-up area; thus this research can demonstrate alternative ways for analysing battles using 3D technologies where extensive, albeit contradictory documentary evidence exists. Since at the time, the British Army only received training for field fighting in open environments (such as the one on the Western Front), it is important as an early example of urban warfare in understanding how a small number of strategically placed combatants, even those with a minimum of military training, as the Irish had, were able to engage and hold off a far superior force over the course of the day.

6. MODELLING THE VIRTUAL WORLD

6.1 Spatial Representations of Battles: From Analogue to Digital

There is a long history of games and simulations invoking dynamic simulations of the physical world used in the training of the military, particularly in terms of strategic training for high ranking officers going back to the Roman Empire [Smith 2010, 6]. Indeed, the game of chess is “one of the most enduring expression of a battle game where two equal opposing forces meet on a board” [Peterson 2016, 4]. While chess is an example of an abstract game of strategy, in the late eighteenth century, Johann Christian Ludwig Hellwig developed a more representational war game which incorporated details of the terrain types (with each square representing two-thousand paces across) and reclassified chess pieces

30

31

32

into branches of the military. Although Hellwig's games were used by his contemporaries to fight both imaginary and past battles, ultimately, Hellwig realised that there existed an inverse relationship between introducing increasingly more realistic features into game play in an effort to represent what actually happens on the battlefield and the playability of the game. Hellwig's insight, the trade-off between realism and playability, is still one of the fundamental challenges of wargame design [Peterson 2016, 4–6]. Hence the next generation of war games began to introduce more abstract representations: dispensing with board and chess-like statuettes representing soldiers, replacing them with “small, nondescript wooden blocks” designed to “occupy the exact dimension that troop formations would on the terrain scale” [Peterson 2016, 7–8].

Concerns of time and space, and the trade-offs herein, still occupy the minds of the designers of war games or simulations created for pleasure, as a means to understand the past, or for training purposes (although these goals are not incompatible). In particular, in the case of representing historical events, there exists a tension between what actually occurred and the impossibility of representing a complex, multidimensional event with hundreds or thousands of actors, each making decisions, the vast majority of them lost to time. Nakamura argues that games that attempt to create simulations of past events can be considered “correct” if they present a “reasonable image of the created world” [Nakamura 2016, 46], embedding a narrative and internal consistency that somebody familiar with the event would recognise. Jettisoning what the designers of the simulation consider extraneous to the narrative is not unlike the choices film directors make when (re)constructing historical events to create a real-time aesthetic. Both film (through narration) and simulations (through interactivity) remediate events and hence the temporal engagement of their viewers/users in the construction of historical time [Crogan 2011, 60–61], albeit through the cultural, political, and social lens of the time in which it was created [Antley 2016, 464].

There are, however, crucial differences in utilising virtual world technologies in the construction of war games in which the simulation typically allows outcomes that are inaccurate historically (see [Crogan 2011, 60] and following; [Nakamura 2016], and [McCall 2016]), and the use of these methods for academic purposes in which a fidelity to historical accuracy is paramount. For example, war games may privilege users' immersion in the virtual environment over accuracy.^[8] They may also lack contextual evidence, again, in the interest of immersivity, although many war games do provide sources from which users make strategic decisions.^[9] Having documentary sources, or annotation, embedded in-world, however, is an inherent feature of 3D Scholarly Editions. Here, the goal is not to have users suspend disbelief through an immersive environment, but to provide a contextualised environment to better understand, and hence draw their own conclusions, about the text, in this case, the created world.

Another key difference between modelling worlds for gaming as opposed to academic purposes is what might be typified as an absence of interaction between the user and the virtual world (e.g. the user is not able to shoot), be among simultaneous users, and the fact that the first-person perspective is not avatar-based. In other words, users cannot see their representation in the world. Computer games typically implement either a first-person avatar-based perspective through which players can see part of the avatar's body, often including hands or a weapon, or a third-person perspective in which the player can see the body of the avatar (for an overview of avatar representation in cultural heritage applications see [Octavian et al. 2018]).

6.2 Modelling the Ambiguity of Primary Data

Because of the constraints of modelling the complexity of real-world events as outlined above, the project sought to implement a “reasonable image of the created world” [Nakamura 2016, 46]. To do this, we employed a wide range of research methods: conventional archival research and meetings with military historians were carried out to document different sources that provide evidence for the buildings that were occupied, participant accounts, and the accuracy of the weapons used. Since period guns were held by our collaborators, we were able to undertake controlled experiments, using shooters of various skill levels, which would have mirrored the situation of the Irish Volunteers. Period photographs and visits to the battlefield, now a peaceful leafy suburban street in Dublin, also enhanced our spatial conception of the event.

Due to the difficulties in mapping time in 3D representations, including technological constraints and the ambiguity of the

sources, many virtual worlds are either atemporal, thus failing to depict the passing of time and how this affects spaces or events, or condense time, for example, by showing changes that occur over a period (from hours to years or even centuries), into short timeframes. Despite the amount of information gathered for the project from a wide range of contemporary and later sources, not surprisingly, the temporal dimension of the battle was, and remains, the most elusive. Although sources give some indication about the sequence of events (e.g. one house was attacked after another), they are rarely clear about the time that a particular event took place, and indeed, are frequently contradictory. Although the release into the public domain of archival material during the project period, including the Bureau of Military History (<http://www.bureauofmilitaryhistory.ie/>) and Military Pension records (<http://www.militaryarchives.ie/collections/online-collections/military-service-pensions-collection/search-the-collection>), provided a wealth of information from the Irish perspective, this often contradicted (rather than confirmed) the British regimental histories written closer in time to the event^[10] [Officers of the Battalions 1921] [Robin Hoods, 1921]. This is because the surviving testimonies carry biases and distortions, sometimes because of the time lag between the event and the recollection (the witness statements of the Irish volunteers were collected some 30 years after the event), other times due to the nature and purpose of the source itself, for example the British Battalion histories, the main sources for the British accounts. These accounts, written by the Officers of the Battalions (published in 1920 and 1921 for the 2/8th and 2/7th respectively) were far more circumspect in providing certain details, which is not surprising given the substantial casualties inflicted on the troops. Therefore, a significant aspect of the research was devoted to evaluating different accounts and problematising their reliability, acknowledging that despite the number of sources collated, a detailed timeline of the battle remains problematic.^[11]

6.3 Designing and Modelling the Virtual World

The project experimented with a number of representations of the world, from more schematic representations (e.g. omitting features such as textures on the buildings, road features, and natural light, Figure 3) to more detailed models that more closely mirrored the built and natural environment (Figure 4). Ultimately, the latter representation was chosen, due in some measure, to a feedback session with a group of military historians fairly early in the development process (see Figure 3) in which it was clear that the absence of realism (e.g. buildings, streets, foliage) as well as more schematic representations of soldiers, did not provide enough context for a primary audience of the research to utilise it.

38

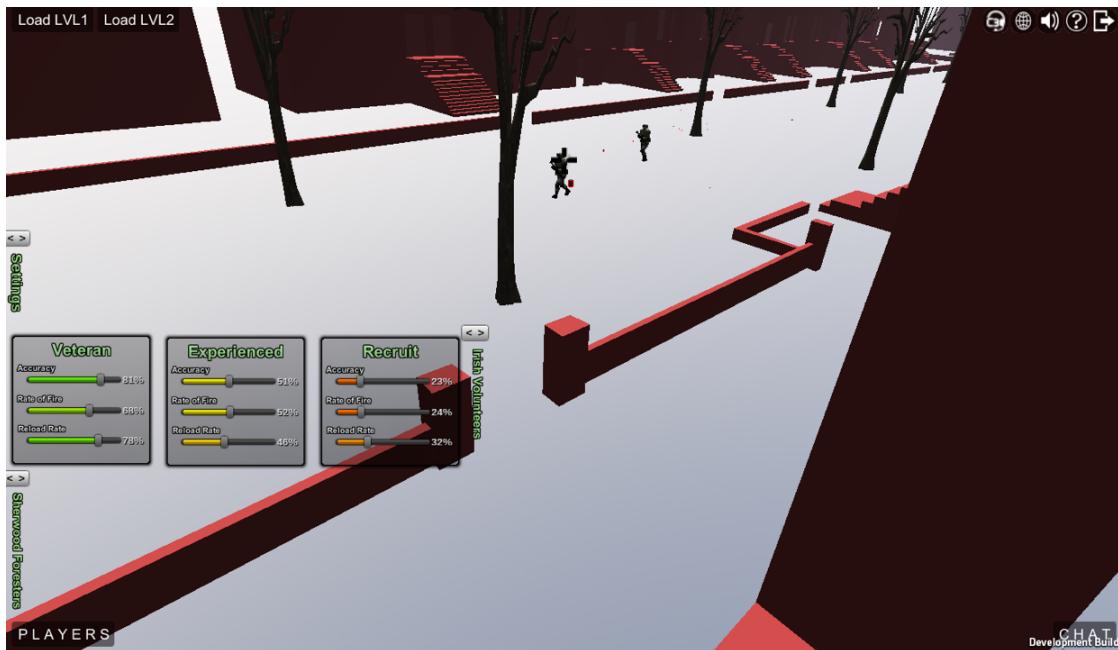


Figure 3. Early prototype of the Battle of Mount Street Bridge in which buildings were schematically constructed and users were able to define the accuracy of the volunteers based on the guns used, i.e., rate of fire, reload rate, and accuracy hitting a target (courtesy of Joshua Savage).

Feedback from the group also strengthened our resolve to have users enter the world disembodied. This decision was taken for several reasons. We had previously decided not to allow users adopt one of the personas engaged in the battle (either one of the named people, such as a Volunteer or an unnamed British soldier) because of the historiography of Irish participation in the Great War. We did not want to encourage users to ‘take sides’ by choosing an avatar, hence affiliating oneself with the British or the Irish. While online war games, even those based on real battles, allow hundreds of players making thousands of decisions, these games loosely follow the battle trajectory. On the other hand, our goal in modelling the battle was to better understand the trajectory of the battle and what conditions afforded the Volunteers such an advantage. We had no wish to allow users to ‘relive’ the battle, nor did we want to glorify it. We also did not want additional avatars in the scene for simultaneous users, even if dressed appropriately for the time, as this would have taken away from the historicity of the created world. The goal was not to allow users to play out a specific battle using Real Time Strategy (RTS) techniques or to provide an immersive experience utilising a First Person Shooter (FPS) perspective, but to use the 3D environment as a way to map the documentary sources onto a 3D plane, emphasising the dialectical and the tactical, allowing simultaneous temporal aspects of the battle to be better understood in a way that simple 2D mapping cannot.

Contrary to many digital (re)constructions of ancient spaces in which architecture is a fundamental research question that helps understand the relationship between people, artefacts, and movement, the area in which the Battle of Mount Street Bridge took place is more or less the same today as in 1916. Although there are buildings that were destroyed during the course of the battle and replaced by modern office blocks (such as Clanwilliam House and Robert’s Builders Yard) the rest of the buildings and the layout of the streets are virtually the same (the main difference being the trees on the street are 100 years older).



Figure 4. Photorealistic rendering of the battlefield in Autodesk 3dsMax including schematic representations of buildings in the adjacent streets.

Unlike the challenges that many wargame designers have faced in terms of designing large battlefields that need to be compressed into a playing field, the Battle of Mount Street Bridge took place in a constrained environment with the majority of action taking place on one city block (Northumberland Road between the Grand Canal and Haddington Road), with forays down adjoining streets around the backs of buildings (Figure 2). Moreover, there exists fairly detailed cross-referenced sources about how the battle was waged spatially, which provided the BMSB team with quite accurate means for the (re)construction.

In order to develop the model a laser scan survey was conducted by Discovery Programme Centre for Archaeological Research and Innovation. Northumberland Road, where most of the events took place, was scanned in its entirety

producing a highly detailed point cloud. The option of using this detailed point cloud for automatic mesh reconstruction was explored, but the models produced were found to be too noisy and computationally intensive for a real-time visualisation. Therefore, the detailed point cloud was only used as an accurate reference to simplify the modelling of the street from scratch.

Constructing the area that was not covered by the point cloud as well as the buildings and structures that are no longer present was achieved by using Google Earth imagery, the 1911 Ordnance Survey map of Dublin, photographs taken after the Rising (particularly of the burnt-out buildings), and site visits. In the case of features that do not exist, perspective and heights in the photographic records and comparison with existing features, such as lamp posts, were used to model these as accurately as possible. On the other hand, for existing structures of the wider area that were not recorded by the laser survey, the PhotoMatch feature in SketchUp was used to generate simple effective textured photogrammetry models from a range of photographs to provide the urban context of battlefield. Finally, for the buildings that had a crucial role in the battle but there is no photographic evidence, such as the Robert's Builders Yard, schematic models rendered in grey were created from the 1911 Ordnance Survey map. The modelled scene was given texture coordinates to enable the accurate lighting and texture in the Unity Engine.

Once the 3D model was completed in 3dsMax, it was exported as an FBX and imported into Unity 3D Version 5.0 as an Asset to enable an in-browser 3D world for users to explore (Figure 5). The real-time interactivity that the platform provides with the free-roaming, user-directed camera contrary to static renderings and predefined animations allows users to explore the space at their own pace without predetermined paths, views, and orientations, thus enabling new discoveries that the modeller or the researchers involved in the decision-making process may not have considered. The camera views in Unity were based on the functionalities developed by the HVWC: Bird's-eye view (from above); near-field view based on movement with WSAD keys; and third-view in which the camera is orbited using the mouse. Users can also "Fly" to observe the scene from different heights.



Figure 5. The Battlefield in Unity 3D Webplayer

The model for the project was developed to be viewed using the Unity Web Player, an NPAPI-based plugin. However, by the end of the first phase of the project in 2016, NPAPI, and consequently the Unity Web Player, was no longer supported by browsers. It was only Firefox that could run BMSB until Spring 2017, which also stopped supporting NPAPI later in the year.^[12] For this reason, the BMSB, similarly to other Unity-based projects, stopped being accessible via a browser. Since the project was committed to providing a publicly-available, online version of our research, the model had to be optimised to run in Unity WebGL, which uses HTML5 technologies and the WebGL rendering API to

run Unity content in a browser (Figure 6). Due to the geometric and textural complexity of the original models, it was necessary to simplify them and find ways to reduce the complexity of the scene, e.g. by reducing the buildings in the background to geometry “instances” that have a much lower memory footprint since they only consist of a reference to the original vertices and textures.



Figure 6. The 3D model of the Battlefield optimized for WebGL

6.4 Implementing a 3D Scholarly Edition

The version of Contested Memories: The Battle of Mount Street Bridge that we have been writing about here can be classified under the “Virtual Museums” category since it is comprised of a digital (re)construction of the battlefield with limited contextual information (e.g. buildings, people, and weapons) included in the website that hosted the virtual world (<https://mountstreet1916.ie/>) and in a sidebar next to the world once launched. However, the project team decided to create bipartite instantiations of the model.

Given the issues in hosting the project online due to the deprecation of Unity’s web player, the optimised WebGL online version has now taken on the role of a more traditional abstract, a taster, or a more condensed version (Figure 6). This means that the online model could run smoothly on most browsers and on much slower computers contrary to the previous Webplayer version. To provide an overview of the battle, there is also a narrative-driven camera in which a voice over, featuring retired Commandant Billy Campbell, one of the researchers on the project, provides an evidence-informed interpretation of how the battle unfolded, while the camera moves concurrently to the various locations. Due to the limitations of the online model, during the narrative the user cannot interact with the scene.

On the other hand, the offline version which utilised the full Unity model is moving towards the paradigm of 3D Scholarly Editions, providing a framework to build a knowledge site, i.e. a single spatio-temporal environment that is immersive and multisensorial that provides the means to: 1) depict ambiguity and make the decision-making process transparent; 2) create annotations that would allow readers to make their own interpretations of the text; and, 3) depict both spatial and temporal aspects of the model. As this is part of a broader effort to develop a 3D edition framework that could be utilised by other Unity-based 3D worlds, the first step in the process was to develop a user-friendly interface that will include generalisable features so other projects can easily use them without the need to develop costly and unsustainable bespoke solutions. The prototype developed for BMSB makes use of clickable hotspots that include annotations for different aspects of the battle (e.g. buildings, volunteers etc.) on a side panel. This can accommodate not only textual information but also multimedia, such as videos recorded during our research in which military experts talk about different aspects of the battle, as well as sound. For example, in one of our visits to the shooting range we recorded the sounds of guns used in the battle. Incorporating these can also work as another cue in developing spatial

46

47

48

awareness and understanding the chaos of echoing [Dinh et al. 1999] [Schmidt 2012], which could have been a critical factor in preventing the British soldiers from determining the exact location of the source of shooting by the Volunteers, especially at the beginning of the battle. Among the features of the 3D Edition is a timeline which indicates the moment an event happened (and/or its duration) also providing relevant annotations on the side panel (Figure 7).

In order to make the addition and updating of annotations easy to handle without the need of any technical expertise, a mechanism that allowed their creation outside the Unity Game Engine was developed. In the first experiments, an online Google spreadsheet was used, in which each line corresponds to a hotspot which has a unique ID and includes all the information that is pulled in the annotation panel. All multimedia are stored in a separate online folder and get connected to the hotspot based on their unique IDs. In such a way any changes in the annotations can be updated within the annotation panel without any Unity or other technical skills. We are currently reworking the spreadsheet into an annotation management system that makes entering and changing information more user friendly. Since the 3D edition framework is still in development and goes beyond the BMSB project, future iterations will also include ways to present alternative reconstructions with associated annotations as well as ways to show different levels of uncertainty, both of which are critical for 3D worlds based on inconsistent and ambiguous primary sources.

The offline version also provided opportunities to experiment with more computationally intensive annotations of the battle. For example, some of the Irish Volunteers described the scene when they saw the seemingly endless formation of British soldiers approaching them. In order to replicate that and due to technical constraints in rendering 1750 realistic soldier representations, we developed a more stylised view by deploying Artificial Intelligence (AI)-driven troop formations, using the Unity plugins Apex Utility AI (<http://apexgamedev.com/products/apex-utility-ai-2/>) and Apex Steer (<http://apexgamedev.com/products/apex-steer/>). (Figure 8)

49

50



Figure 7. The prototype of the 3D Scholarly Edition framework. Clickable hotspots provide multimedia annotations on a side panel, while a timeline indicates the duration or the moment when certain events happened.



Figure 8. A schematic view of the approaching British troops on Northumberland Road using Artificial Intelligence-driven troop formations.

7. CONCLUSION

The 3D world of the Battle of Mount Street Bridge enabled our research team to map our interpretation of documentary evidence and secondary sources on a three-dimensional terrain. Our goal was to stimulate a wider discussion and to enlarge the palette of creative responses to the event which had been long stuck in an Irish vs British, victor vs loser mode, along with hyperbolic and largely unproven claims. Our goal, as with many other research projects in employing these methods, was that introducing 3D modelling would have a transformative impact on sense-making, reasoning, and understanding through the process of problematising sources, identifying variables, and justifying solutions, opening a dialogue to generate new avenues of scholarship unlike the traditional spatiotemporal approaches that had been used in the past. 51

The technical challenges encountered by the BMSB project, and also the myriad of projects no longer accessible outlined above, highlight the precariousness of working with these technologies [McDonough et al. 2010] [Ruan and McDonough 2009] [Archaeology Data Service/Digital Antiquity 2011]). The instability of the research environment is a deterrent to more researchers working with such methods, since even when virtual worlds can be ported from one framework to another, this involves significant costs, downsampling and even rebuilding models, and repurposing content that cannot be fully migrated. Not only have we grown accustomed to expecting research outputs being available for hundreds of years in print-based environments, but for text-based digital scholarship, much of which has lasted decades, there exists models for preservation. 52

Despite these challenges, in the case of the BMSB project, there was no doubt amongst the project team, that it was only after we had the opportunity to navigate the photorealistic virtual world accompanied by a live narration by our collaborator Retired Commandant Billy Campbell describing the movements of the British soldiers that we managed to create a mental map of how and when the battle unfolded, which in turn affected our perception of the actual battlefield. The 3D world provided us a palette from which to map the battle in four dimensions, with actors moving concurrently in space over time. Early attempts to achieve this (before the 3D models were available) using more conventional methods (eg. spreadsheets and 2D maps) lacked an aspect of this multi-dimensionality, allowing us to only partially reconstruct spatial/temporal aspects of the battle. Moreover, despite having repeatedly walked the battlefield and extensively discussed the sequence and details of the various events, it was our experience of the 3D world with its vantage and viewpoints (whether flying above the world, looking out from a window in which a Volunteer stood, or being on the spot where the fighting broke out, without the distraction of present-day traffic and pedestrians) that provided us with a sense of presence [Heeter 1992] [Steuer 1992] and solidified our understanding of the trajectory of the battle. 53

The model was crucial in answering the primary research question with which the project began: e.g. how many British casualties did the British forces suffer at this battle. The model in and of itself did not provide the answer: this was arrived at through exhaustive research into primary and contemporary secondary sources (for more details on this aspect of research see [Hughes et al. 2017]). What the world provided us with, however, was an understanding of *how* 54

this could happen. As stated above, while the figure for casualties (both killed and wounded) most cited is 234, given by General Sir John Maxwell, our research provided us with a more nuanced figure of 26 killed and 124 wounded. While this is not an insignificant figure, it is far lower than Maxwell's more contemporary report, with a more precise number for those killed. Of the wounded, the discovery of a journal at the Bodleian Library of lists of casualties provided us with a more nuanced understanding of the range of reasons men presented with wounds: from wounds to the body to sprained ankles to shock. Typically, only body parts are listed in these reports: throat, hand, thigh, which in many instances we can presume were caused by bullets (throat, thigh); others, such as head, hand, ankle, are not as clear as these may have also been the result of sprains and falls [Nathan 1916]. The very low ratio of wounded to dead may have also been due to the triage by medical personnel who were reported in multiple sources as being on site for the duration of the battle and able to provide immediate medical care (see for example, [Robin Hoods, 1921, 288]; [Oates 1920, 42]). Our much lower figure of troops that were killed also maps onto the preparedness of the Volunteers who had reasonable training, albeit not always with live ammo [Hughes et al. 2017, 15] coupled with an odd assortment of guns each with limited and not-interoperable ammo. Nevertheless, they were firing into, in military terms, a "target rich environment" with hundreds of troops within range.

The model, above all, provided us with a way to map, both temporally and spatially, the unfolding of the battle as the buildings held by the Volunteers were captured or vacated, as well as the complex movements of hundreds of British troops at any given time as various companies made flanking movements, attempting to find alternative routes to approach Mount Street Bridge, not knowing whether or where the Volunteers had occupied other buildings. The photorealistic rendering of the world provided us with clearer evidence than a two-dimensional map did of the terrain of the battlefield: eg., the lack of cover, the obstacles in the way of storming buildings (such as the high rails typically fronting each house). The high casualty figures may also be due to the British troops' lack of experience. They were still in early days of training for the open fields of the Western Front which included no training for warfare in an urban or built-up environment. This dimensionality provided us with a tangible fourth dimension which helped us resolve conflicting information about how the battle unfolded in time. An example of this is the fall of 25 Northumberland Road, the first building captured by the British. The 2/7th battalion history claims the unit had taken the building soon after 2.45pm [Oates 1920, 285] while the sole survivor, Grace, placed it c. 8.30 pm, which is unrealistically late given other events for which we have more precise timings [Grace n.d., 9]. Given the beginning of the battle around noon, and the accounts of other buildings north of 25 having vacated by early evening, the model provided us with an environment from which we could map and remap our evidence, arriving at a more comprehensive and source-driven picture of the event.

At the same time, the BMSB project has been used as a test case to explore how to integrate a 3D visualisation as the primary text of a digital scholarly edition, raising issues of how the phenomenology of place and space can be used to design a new language of scholarly editions, one that has the ability to model experience lost because of technological and evidentiary constraints [Schreibman 2013]. This edition, like traditional DSEs, also brings together documentary evidence in the form of apparatus, reimagining digital textuality. We argue that the theories behind digital scholarly editing can be used as a theoretical and representational scaffolding to historical modelling in 3D to provide a framework from which to construct the world as well as for readers to understand the rationale and decision-making that underpins the creation of the world (for a discussion of the framework see [Schreibman and Papadopoulos 2019]). At the same time, such a framework provides us with the means to valorise and to evaluate 3D visualisation scholarship, utilising similar principles to the ways in which we valorise and evaluate more established scholarly outputs [Sullivan et al 2018].

Despite the constantly evolving landscape in which we do research, 3D (re)constructions provide both modellers and users with an advanced understanding of spatial and temporal dimensions of past environments. Although research is yet inconclusive regarding virtual world features that generate a sense of presence in these environments, e.g. textual annotation, storytelling, sound, visual realism etc. [Pujol 2019], we believe that by combining two seemingly incompatible paradigms, our work provides a framework for infusing 3D worlds with a hermeneutic richness [Champion 2015] consisting of visual and auditory immersion and dynamic annotative features that will enhance the interactivity of the medium.

55

56

57

ACKNOWLEDGMENTS

The authors acknowledge the many people who have contributed to the BSBM project. Particular thanks go to John Buckley for modelling the virtual world in Unity 3D and WebGL and to Almants Auksconis for his work on AI agents. Also, to Noho, and particularly Klemens Kopetzky and Niall Ó hOisín for their work on the 3D Scholarly Edition framework. Thanks go to Hugh Denard for his early work in conceptualising and framing the BMSB project. Thanks also go to Neale Rooney, Vinayak Das Gupta, and Roman Bleier for their help in developing the initial interface for the project, to Joshua Savage for his work on the early feedback session, and to Retired Commandant Billy Campbell, Brian Hughes, and Commandant Alan Kearney for their expertise in the historical and military aspects of the project. A special thanks goes to the Andrew W. Mellon Foundation who funded the initial development of the BMSB project as part of the Humanities Virtual Worlds Consortium, the Digital Scholarly Editions Initial Training Network (DiXIT) for supporting its redevelopment, and The National Historical Publications and Records Commission (NHPRC) and Andrew W. Mellon Foundation for funding our work on 3D Editions as part of the Scholarship in 3D project.

58

Notes

[1] For an earlier classification of virtual worlds see Champion and Dave (2007) “Dialing up the Past”, who divided virtual worlds into spatially visualised, activity-based, and hermeneutic in a pursuit of placemaking in such environments and in response to Kalay’s and Marx’s (2005) cyber-placemaking. Also see Anderson et al. (2010) on a typology for serious games.

[2] For representative examples of standalone, offline 3D projects that have been used to analyse spatial and temporal features in past environments see: [Gutierrez et al. 2007]; [Dylla et al. 2010]; [Anderson et al. 2010]; [Paliou et al. 2011]; [Papadopoulos and Earl 2014].

[3] In the simplest case, in editing a manuscript for print publication an editor must make decisions in interpreting characters or words, in the case of deletions and additions, in what order the text should be presented, and in manuscripts that contain multiple texts, if portions should be considered part of the work being edited or of another work. More complex editing may involve creating the text from multiple extant versions (or witnesses) in which no single version carries final authorial intention.

[4] Editorial theory covers a wide range of practices and documentary types. For example, documentary editing is typically used for historical texts that exist in one version in which the manuscript is reproduced in print as accurately as possible (e.g. without correction of spelling, with additions and deletions, etc.). Genetic editing is typically used for manuscripts of literary texts in which the author has significant revision on the page. Here the goal of the editorial process is to understand the thought process of the author through the revision process.

[5] This project has been built and can be accessed by using the Blue Mars Virtual World Platform (<http://www.bluemars.com/>). At the moment of writing this paper the Blue Mars Client and consequently the Ball Glass Factory Virtual World was not accessible. John Fillwalk kindly provided a stand-alone version of the virtual world.

[6] Due to the Unity Webplayer technology no longer being supported by web browsers, the project cannot be accessed online. The PI, Angel D. Nieves, is currently working on a WebGL version as part of the “Scholarship in 3D” project funded by the National Historical Publications and Records Commission and the Andrew W. Mellon Foundation.

[7] The authors currently are exploring the affordances of 3D Scholarly Editions as part of the “Scholarship in 3D” project that is creating a new paradigm for reconceiving 3D models as academic outputs by establishing a publishing cooperative with the necessary open-source infrastructure, workflows, and peer-reviewing guidelines.

[8] There are war games that have invested in both realism and accuracy. For example, the development of the multiplayer first-person shooter game, Verdun (<https://www.verdungame.com/>), included historical research to accurately depict weapons, uniforms, and battlefields, as well as bullet physics.

[9] In the war game, Battlefield 1 (<https://www.battlefield.com/>), players have to complete certain challenges, called Codex Entries, to unlock information written by military and WWI historians. One of these, refers to “Dicta Boelcke”, a list of aerial combat techniques for attack procedures and tactics written by the German flying Ace, Oswald Boelcke.

[10] Battalion histories for the 2/7th and the 2/8th Battalions of the Sherwood Foresters exist, each with extensive accounts of the battle.

[11] For a detailed historical account of the battle, see [Hughes et al. 2017].

[12] Alternative web players, such as Gameload <www.gameload.top> can be installed as an extension to Chrome in Windows PCs, thus enabling an in-browser activation of a Unity game. Unity virtual worlds mentioned in Section 1 “Historical Virtual Worlds: The Challenges of the State-of-the-Art” that were still available online were opened at the time of writing this paper using Gameload; however, due to the instability of the application (often needed to be reinstalled to run properly) navigation features were disabled in many of these.

Works Cited

- Anderson et al. 2010** Anderson, E.F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P., de Freitas, S. “Developing Serious Games for Cultural Heritage: A State-of-the-Art Review”. *Virtual Reality* 14.4: 255-275. Retrieved November 5, 2017, DOI: <https://doi.org/10.1007/s10055-010-0177-3>
- Antley 2016** Jeremy, A. “Struggling with Deep Play.” In P. Harrigan and M. G. Kirschenbaum (eds) *Zones of Control: Perspectives on Wargaming* (2016), Cambridge, Massachusetts, MIT Press, pp. 463-470.
- Apollon et al. 2014** Apollon D., Bélisle, C. and Régnier, P. (eds) *Digital Critical Editions*. Urbana, Illinois, University of Illinois Press (2014).
- Archaeology Data Service/Digital Antiquity 2011** Archaeology Data Service Guide to Archiving Virtual Reality Projects (2011). http://guides.archaeologydataservice.ac.uk/g2gp/Vr_6-1.
- Barthes 1977** Barthes, R. *Image-Music-Text. Essays selected and translated by Stephen Heath*. London, UK, Fontana (1977).
- Beacham 2009** Beacham, R. THEATRON Final Report. London, King’s College London (2009). Retrieved November 6, 2017 from: http://cms.cch.kcl.ac.uk/theatron/fileadmin/templates/main/THEATRON_Final_Report.pdf
- Bell 2008** Bell M., “Toward a Definition of ‘Virtual Worlds’,” *Journal of Virtual Worlds Research*, 1.1 (2008). Retrieved November 5, 2017 from: <https://journals.tdl.org/jvwr/index.php/jvwr/article/view/283/237>
- Bornstein and Williams 1993** Bornstein G. and Williams, R.G. *Palimpsest: Editorial Theory in the Humanities*. Ann Arbor, Michigan, University of Michigan Press (1993).
- Burnard et al. 2006** Burnard, L., O’Brien O’Keefe, K., and Unsworth, J.(eds). *Electronic Textual Editing*. New York, NY, Modern Language Association (2006).
- Champion 2015** Champion, E., 2015. “Role-Playing and Rituals for Cultural Heritage-Oriented Games” *Diversity of play: Games – Cultures – Identities: Proceedings of DIGRA 2015*, Lüneberg, Germany, 14-17 May 2015.
- Champion and Bharat 2007** Champion, E. and Bharat D., “Dialing up the Past.” In F. Cameron and S. Kenderdine (eds), *Theorizing Digital Cultural Heritage: A Critical Discourse*, Cambridge, Massachusetts, MIT Press (2007), pp. 333-348.
- Crogan 2011** Crogan, P. *Gameplay Mode: War, Simulation, and Technoculture*. Minneapolis, Minnesota, University of Minnesota Press (2011).
- Dawson et al. 2007** Dawson, P., Levy, R., Gardner, D. and Walls, M. “Simulating the Behavior of Light Inside Arctic Dwellings: Implications for Assessing the Role of Vision in Task Performance”, *World Archaeology*, 39.1 (2007): 17–55, Retrieved November 5, 2017, DOI: <http://dx.doi.org/10.1080/00438240601136397>
- Dinh et al. 1999** Dinh, Q. H., Walker, N., Song, C., Kobayashi, A., and Hodges, F.L. “Evaluating the Importance of Multi-sensory Input on Memory and the Sense of Presence in Virtual Environments” *Proceedings of the IEEE Virtual Reality - VR ’99* (1999). IEEE Computer Society, Washington, DC, USA, pp. 222-229.
- Djurcillo et al. 2001** Djurcillo, S., Kwansik, K., Lermusiaux, P.F.J. and Pang, A. “Volume Rendering Data with Uncertainty Information.” In Ebert, D.S., Favre, J.M., and Peikert, R. (eds) *Proceedings of the 3rd Joint Eurographics - IEEE TCVG Conference on Visualization*, Aire-la-Ville, Switzerland: Eurographics Association Switzerland (2001), pp. 243-252 Retrieved November 6, 2017, DOI: <http://dx.doi.org/10.2312/VisSym/VisSym01/243-252>
- Driscoll and Pierazzo 2016** Driscoll J. M. and Pierazzo, E. (eds). *Digital Scholarly Editing: Theories and Practices*. Cambridge, Open Book Publishers (2016).
- Dylla et al. 2010** Dylla, K., Frischer, B., Mueller, P., Ulmer, A., and Haegler, S. “Rome Reborn 2.0: A Case Study of Virtual City Reconstruction Using Procedural Modeling Techniques.”, In B. Frischer, J. Webb Crawford, and D. Koller (eds), *Making History Interactive. Computer Applications and Quantitative Methods in Archaeology (CAA)*. Proceedings of the 37th International Conference, Williamsburg, Virginia, United States of America, March 22-26 (BAR International Series S2079). Archaeopress, Oxford (2010), pp. 62-66.

Earle and Hales 2009 Earle, N. and Hales, S. "Pompeii in the Crystal Palace: Comparing Victorian and Modern Virtual, Immersive Environments" Proceedings of Electronic Visualisation in the Arts Conference, Swindon, UK, BCS Learning & Development Ltd. (2009), pp. 37-46.

Earle et al. 2011 Earle, N., Hales, S., Moseley, T. and Thorne, H. Crystal Palace Project and Chantry High School Evaluation Report. Bristol, University of Bristol (2011). Retrieved November 6, 2017 from: <https://sydenhamcrystalpalace.files.wordpress.com/2011/10/evaluation-report-july-2011.pdf>

Eiteljorg 2000 Eiteljorg II H. "The Compelling Image – A Double Edged Sword", Internet Archaeology, 8. Retrieved November 6, 2017, DOI: <https://doi.org/10.11141/ia.8.3>

Fischer 2011 Fischer, L. "Visualizing Williamsburg: Modeling an Early American City in 2D and 3D." In F. Niccolucci, M. Dellepiane, S. Pena Serna, H. Rushmeier and L. Van Gool (eds), VAST11: International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage (2011), pp. 77-80. The Eurographics Association. Retrieved November 6, 2017, DOI: <http://dx.doi.org/10.2312/PE/VAST/VAST11S/077-080>

Folsom and Price 2017 Folsom, E. and Price, K.M. The Walt Whitman Archive. Last Modified September 2017. Retrieved November 6, 2017 from: <http://whitmanarchive.org/>

Frischer and Stinson 2003 Frischer, B. and Stinson, P. "The Importance of Scientific Authentication and a Formal Visual Language in Virtual Models of Archaeological Sites: The Case of the House of Augustus and Villa of the Mysteries." In N. A. Silberman and D. Callebaut (eds) Proceedings of the Interpreting the Past: Heritage, New Technologies and Local Development Conference on Authenticity, Intellectual Integrity and Sustainable Development of the Public Presentation of Archaeological and Historical sites and Landscapes (2003), pp. 49-83. Brussels, Flemish Heritage Institute. Retrieved November 6, 2017 from: http://www.iath.virginia.edu/images/pdfs/frischer_stinson.pdf

Frischer et al. 2016 Frischer, B., Zotti, G., Mari, Z., Capriotti Vittozzi, G. "Archaeoastronomical Experiments Supported by Virtual Simulation Environments: Celestial Alignments in the Antinoeion at Hadrian's Villa (Tivoli, Italy)," Digital Applications in Archaeology and Cultural Heritage, 3. 3 (2016): 55-79. Retrieved November 6, 2017, DOI: <http://dx.doi.org/10.1016/j.daach.2016.06.001>

Frischer et al. 2017 Frischer B., Pollini, J., Cipolla, N., Capriotti, G., Murray, J. et al. "New Light on the Relationship Between the Montecitorio Obelisk and Ara Pacis of Augustus." Studies in Digital Heritage, 1. 1 (2017). Retrieved November 6, 2017, DOI: <https://doi.org/10.14434/sdh.v1i1.23331>

Girvan 2013 Girvan, C. What is a Virtual World? Definition and Classification. Dublin, Ireland: School of Computer Science and Statistics (SCSS) at Trinity College Dublin (2013). Retrieved November 6, 2017 from <https://www.scss.tcd.ie/publications/tech-reports/reports.13/TCD-CS-2013-10.pdf>

González-Tennant 2013 González-Tennant, E. "New Heritage and Dark Tourism: A Mixed Methods Approach to Social Justice in Rosewood, Florida", Heritage and Society, 6. 1 (2013): 62-88, Retrieved November 6, 2017, DOI: <http://dx.doi.org/10.1179/2159032X13Z.0000000007>

González-Tennant 2015 González-Tennant, E. "Resurrecting Rosewood: New Heritage as Applied Visual Anthropology." In A. Gubrium, K. Harper and M. Otanez (eds), Participatory Visual and Digital Research in Action, Walnut Creek, California, Left Coast Press (2015), pp. 163-180.

Grace n.d. Bureau of Military History Witness Statement. James Grace Witness Statement, BMH WS 310.

Gutierrez et al. 2007 Gutierrez, D., Frischer, B., Cerezo, E., Gomez, A., Serona, F. "AI and Virtual Crowds: Populating the Colosseum", Journal of Cultural Heritage, 8 (2007): 176-185, Retrieved November 6, 2017, DOI: <https://doi.org/10.1016/j.culher.2007.01.007>

Heeter 1992 Heeter, C. "Being There: The Subjective Experience of Presence", Presence: Teleoperators and Virtual Environments, 1.2 (1992): 262 -271.

Hockey 2000 Hockey, S. Electronic Texts in the Humanities. Oxford, Oxford University Press (2000).

Hughes et al. 2017 Hughes, B., Campbell, B. and Schreibman, S. "Contested Memories: Revising the Battle of Mount Street Bridge, 1916", British Journal of Military History, 4.1 (2017): 2-22, Retrieved November 7, 2017 from: <http://www.bjmh.org.uk/index.php/bjmh/article/view/192/154>

Kalay and Marx 2005 Kalay, Y. and Marx, J. "Architecture and the Internet: Designing Places in Cyberspace", First Monday, 5, Special Issue: Virtual Architecture at State of Play III (2005). Retrieved November 6, 2017, DOI: <http://dx.doi.org/10.5210/fm.v0i0.1563>

Kensek 2007 Kensek, K. "Survey of Methods for Showing Missing Data, Multiple Alternatives, and Uncertainty in

Reconstructions”, CSA Newsletter, 19, 3. Retrieved November 6, 2017 from:
<http://csanet.org/newsletter/winter07/nlw0702.html>

Kraus and Donahue 2012 Kraus, K. and Donahue, R. “‘Do You Want to Save Your Progress?’: The Role of Professional and Player Communities in Preserving Virtual Worlds”, Digital Humanities Quarterly, 6, 2 (2012). Retrieved November 6, 2017 from: <http://www.digitalhumanities.org/dhq/vol/6/2/000129/000129.html>

Laycock et al. 2008 Laycock, R. G., Drinkwater, D., and Day, A. M. “Exploring Cultural Heritage Sites through Space and Time”, Journal on Computing and Cultural Heritage, 1. 2, Article 11 (2008), DOI:
<https://doi.org/10.1145/1434763.1434768>

McCall 2016 McCall, Jeremiah. “Teaching History with Digital Historical Games: An Introduction to the Field and Best Practices”, Simulation & Gaming, 47, 4 (2016): 517-542. Retrieved November 6, 2017, DOI:
<https://doi.org/10.1177/1046878116646693>

McDonough et al. 2010 McDonough, J., Olendorf, R., Kirschenbaum, M., Kraus, K., Reside, D. et al. Preserving Virtual Worlds Final Report. Illinois, IDEALS, Illinois Digital Environment for Access to Learning and Scholarship (2010). Retrieved November 6, 2017 from: <http://hdl.handle.net/2142/17097>

McKenzie 1999 McKenzie, F. D. Bibliography and the Sociology of Texts. Cambridge, Cambridge University Press (1999).

Morgan 2009 Morgan, C., “(Re)Building Çatalhöyük: Changing Virtual Reality in Archaeology”, Archaeologies, 5 (2009): 468-487, Retrieved November 6, 2017, DOI: <https://doi.org/10.1007/s11759-009-9113-0>

Nakamura 2016 Nakamura, T. “The Gap Between Tabletop Simulations Games and the ‘Truth’.”. In P. Harrigan and M. G. Kirschenbaum (eds), Zones of Control: Perspectives on Wargaming, Cambridge, Massachusetts, MIT Press (2016), pp. 43-47.

Nathan 1916 Papers of Sir Matthew Nathan, Rebellion in Ireland, Vol. 1, MS 476 & Vol. II, MS 477 Casualty lists by day, 26 April-5 May. Bodleian Library, Oxford.

Nevelsteen 2017 Nevelsteen, K., “Virtual World, Defined from a Technological Perspective, and Applied to Video Games, Mixed Reality and the Metaverse”, Computer Animation & Virtual Worlds (2017), Retrieved November 5, 2017, DOI: <http://doi.org/10.1002/cav.1752>

Newman 2016 Newman R. W. The Chymistry of Isaac Newton. Last Modified December 4, 2016. Retrieved November 6, 2017 from: <http://webapp1.dlib.indiana.edu/newton/>

Niccolucci and Hermon 2002 Niccolucci, F. and Hermon, S. “A Fuzzy Logic Approach to Typology in Archaeological Research.” In M. Doerr and A. Sarris (eds), The Digital Heritage of Archaeology. Proceedings of Computer Applications and Quantitative Methods in Archaeology, Heraklion, Hellenistic Ministry of Culture, Greece (2002), pp 307-312. Retrieved November 6, 2017 from: https://bibliographie.uni-tuebingen.de/xmlui/bitstream/handle/10900/62210/03_Niccolucci_Hermon_CAA_2004.pdf?sequence=2&isAllowed=y

Oates 1920 Oates, W. C. The Sherwood Foresters in the Great War: 1914-1918. The 2/8th Battalion. Nottingham, J. & H. Bell Limited.

Octavian et al. 2018 Octavian, M., Machidon, M. O., Duguleana, M., and Carrozzino, M. “Virtual Humans in Cultural Heritage ICT Applications: A Review”. Journal of Cultural Heritage, 33 (2018): 249-260, Retrieved June 9, 2019, DOI: <https://doi.org/10.1016/j.culher.2018.01.007>

Oetelaar 2016 Oetelaar, T., “CFD, Thermal Environments, and Cultural Heritage: Two Case Studies of Roman Baths.” In IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), Florence, Italy, IEEE (2016), Retrieved November 5, 2017, DOI: <http://doi.org/10.1109/EEEIC.2016.7555484>

Officers of the Battalions 1921 Officers of the Battalions. The Robin Hoods. 1/7th, 2/7th & 3/7th Battns. Sherwood Foresters: 1914-1918. Nottingham, J. & H. Bell Limited (1921).

Paliou et al. 2011 Paliou, E., Wheatley, D., and Earl, G. “Three-dimensional Visibility Analysis of Architectural Spaces: Iconography and Visibility of the Wall Paintings of Xeste 3 (Late Bronze Age Akrotiri)”, Journal of Archaeological Science, 38.2 (2011): 375-386, Retrieved November 5, 2017, DOI: <https://doi.org/10.1016/j.jas.2010.09.016>

Papadopoulos and Earl 2009 Papadopoulos, C. and Earl, G.P. “Structural and Lighting Models for the Minoan Cemetery at Phourni, Crete.” In Debbatista, K., Perlingieri, C., Pitzalis, D., and Spina, S. (eds), Proceedings of the 10th International conference on Virtual Reality, Archaeology and Cultural Heritage, Aire-la-Ville, Switzerland, Eurographics Association (2009), pp. 57-64. Retrieved November 6, 2017, DOI: <http://dx.doi.org/10.2312/VAST/VAST09/057-064>

Papadopoulos and Earl 2014 Papadopoulos, C. and Earl, G. “Formal Three-dimensional Computational Analyses of

Archaeological Spaces.” In E. Paliou, U. Lieberwirth and S. Polla (eds), *Spatial Analysis and Social Spaces. Interdisciplinary Approaches to the Interpretation of Prehistoric and Historic Built Environments*, Berlin, Boston, De Gruyter (2014), pp. 135-166.

Peterson 2016 Peterson, J. “A Game Out of All Proportions.” In P. Harrigan and M.G. Kirschenbaum (eds), *Zones of Control: Perspectives on Wargaming*, Cambridge, Massachusetts, MIT Press (2016), pp. 3-31.

Pierazzo 2015 Pierazzo, E. *Digital Scholarly Editing: Theories, Models and Methods*. Surrey, UK, Routledge (2015).

Pollini et al. 2005 Pollini, J., Dodd, L.S., Kensek, K., Cipolla, N. “Problematics of Making Ambiguity Explicit in Virtual Reconstructions: A Case Study of the Mausoleum of Augustus.” In A. Bentkowska-Kafel, T. Cashen and H. Gardiner (eds) *Theory and Practice. Proceedings of the 21st Annual Conference of CHArt: Computers and the History of Art*, London, British Academy (2005).

Pujol 2019 Pujol, L. “Did we just travel to the past? Building and evaluating with Cultural Presence different modes of VR-mediated experiences in Virtual Archaeology”, *ACM Journal on Computing and Cultural Heritage*, 12, 1 (2019), Retrieved March 18, 2019, DOI: <https://doi.org/10.1145/3230678>

Reilly 2016 Reilly, P., Todd, S. and Walker, A. “Rediscovering and Modernising the Digital Old Minster of Winchester”, *Digital Applications in Archaeology and Cultural Heritage*, 3, 2 (2016): 33–41, Retrieved November 5, 2017, DOI: <https://doi.org/10.1016/j.daach.2016.04.001>

Roberts and Ryan 1997 Roberts C. J. and Nick Ryan. “Alternative Archaeological Representations within Virtual Worlds” In R. Bowden (ed.) *Proceedings of the 4th UK Virtual Reality Specialist Interest Group Conference – Brunel University*, Brunel, Brunel University Printing Services (1997), pp. 179-188. Retrieved November 5, 2017 from <https://www.cs.kent.ac.uk/pubs/1997/522/>

Robin Hoods, 1921 Written by Officers of the Battalions, “The Robin Hoods: 1/7th, 2/7th & 3/7th Battalions, Sherwood Foresters, 1914-1918”, Nottingham: J. & H. Bell.

Ruan and McDonough 2009 Ruan J. and McDonough, J.P. “Preserving Born-digital Cultural Heritage in Virtual World.” In IEEE International Symposium on IT in Medicine & Education, Jina, China: IEEE (2009), pp. 745-748. Retrieved November 6, 2017. DOI: <http://ieeexplore.ieee.org/document/5236324/>

Schmidt 2012 Schmidt, M., Schwartz, S., and Larsen, J. “Interactive 3-D Audio: Enhancing Awareness of Details in Immersive Soundscapes?”, *Audio Engineering Society, Convention 133* (2012). Audio Engineering Society.

Schreibman 2013 Schreibman, S. “Digital Scholarly Editing.” In K.M. Price and R. Siemens (eds), *Literary Studies in the Digital Age: An Evolving Anthology* (2013). MLA Commons. Retrieved November 6, 2017, DOI: <https://doi.org/10.1632/lsla.2013.4>

Schreibman and Papadopoulos 2019 Schreibman, S. and Papadopoulos, C. “Textuality in 3D: Three-dimensional (Re)constructions as Digital Scholarly Editions”. *International Journal of Digital Humanities. Special Issue: Digital Scholarly Editing*. Springer, DOI: <https://doi.org/10.1007/s42803-019-00024-6>

Schroeder 2008 Schroeder, R. “Defining Virtual Worlds and Virtual Environments”, *Journal of Virtual Worlds Research* 1.1 (2008), Retrieved November 5, 2017 from <https://journals.tdl.org/jvwr/index.php/jvwr/article/view/294/248>

Sequiera and Morgado 2013 Sequiera M. L. and Morgado, L. C. “Virtual Archaeology in Second Life and OpenSimulator”, *Journal of Virtual Worlds Research* 6.1 (2013): 1-16, Retrieved November 5, 2017 from: <https://journals.tdl.org/jvwr/index.php/jvwr/article/view/7047/6310>

Shillingsburg 1996 Shillingsburg, P.. *Scholarly Editing in the Computer Age: Theory and Practice*. Third Edition. Ann Arbor, Michigan, University of Michigan Press (1996).

Smith 2010 Smith, R. “The Long History of Gaming in Military Training”, *Simulation & Gaming*, 41.1 (2010): 6-19. Retrieved November 6, 2017, DOI: <https://doi.org/10.1177/1046878109334330>

Snyder 2014 Snyder, L. M. “VSim: Scholarly Annotations in Real-Time 3D Environments”. In P. Schmitz, L. Pearce, and Q. Dombrowski (eds) *DH-CASE II: Collaborative Annotations on Shared Environments: Metadata, Tools and Techniques in the Digital Humanities (DH-CASE 2014)*, ACM, New York, NY, USA, Article 2, 8 pages. DOI: <http://dx.doi.org/10.1145/2657480.2657483>

Stefani et al. 2008 Stefani, C, De Luca, L, Véron, P, Florenzano, M. “Reasoning About Space-Time Changes: An Approach for Modeling the Temporal Dimension in Architectural Heritage.” In Y. Xiao and E. ten Thij (eds) *Proceedings of the IADIS International Conference on Computer Graphics and Visualization*. Amsterdam, The Netherlands 22-27 July 2008, pp. 287-292.

Steuer 1992 Steuer, J. "Defining Virtual Reality: Dimensions Determining Telepresence", *Journal of Communication*, 42.4 (1992): 73–93.

Strothotte et al. 1999 Strothotte, T., Masuch, M. and Isenberg, T. "Visualizing Knowledge about Virtual Reconstructions of Ancient Architecture." In *Proceedings of the International Conference on Computer Graphics - CGI '99* (1999), Washington, DC: IEEE, pp. 36-43. Retrieved November 6, 2017 DOI: <https://doi.org/10.1109/CGI.1999.777901>

Sullivan and Snyder 2017 Sullivan, E. A., and Snyder, L.M. "Digital Karnak: An Experiment in Publication and Peer Review of Interactive, Three-Dimensional Content." *Journal of the Society of Architectural Historians* 76. 4 (2017): 464-482.

Sullivan et al 2018 Sullivan, E, Nieves, A. D., and Snyder, L. M. "Making the Model: Scholarship and Rhetoric in 3D Historical Reconstructions." In J. Sayers (ed.) *Making Things and Drawing Boundaries: Experiments in the Digital Humanities*. University of Minnesota Press.

Sutherland 1997 Sutherland, K. *Electronic Text: Investigations in Method and Theory*. Oxford, Clarendon Press (1997).

Tringham 2009 Tringham, R. Okapi Island Machinima: The Hunt. Created [Fall 2009]. YouTube Video, 4:05. Posted [July 2016]. Retrieved November 6, 2017 from: <https://youtu.be/n86eZOr-9xE>

Vosinakis and Avranidis 2016 Vosinakis, S. and Avradinis, N. "Virtual Agora: Representation of an Ancient Agora in Virtual Worlds using Biologically-inspired Motivational Agents", *Mediterranean Archaeology and Archaeometry*, 16, 5 (2016): 29-41. Retrieved November 6, 2017, DOI: <https://doi.org/10.5281/zenodo.204964>

Wankel and Kingsley 2009 Wankel, C. and Kingsley, J. (eds). *Higher Education in Virtual Worlds: Teaching and Learning in Second Life*. Bingley, UK, Emerald Group Publishing Limited (2009).

Zuk et al. 2005 Zuk, T., Carpendale, S., and Glanzman, W.D. "Visualizing Temporal Uncertainty in 3D Virtual Reconstructions." In M. Mudge, N. Ryan, R. Scopigno (eds), *Proceedings of the 6th International conference on Virtual Reality, Archaeology and Intelligent Cultural Heritage - VAST'05* (2005), Eurographics Association, Aire-la-Ville, Switzerland, Switzerland, pp. 99-106, DOI: <http://dx.doi.org/10.2312/VAST/VAST05/099-106>