The Digital Hadrian’s Villa Project
Using Virtual Worlds to Control Suspected Solar Alignments

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Abstract—This paper discusses how the Digital Hadrian’s Villa Project has used virtual world technology to control the validity of a claimed alignment between the sun’s position at sunset on the summer solstice during the reign of Hadrian (117-138 CE) and the tower structure at Hadrian’s Villa known as Roccabruna. The conclusion is reached that virtual world technology is usefully applied in investigations of this kind.

Keywords- virtual worlds, archaeoastronomy, Hadrian’s Villa, Unity3D, C3, solar tracking, NASA Horizons System

I. INTRODUCTION

Hadrian’s Villa is the best known and best preserved of the imperial villas built in the hinterland of Rome by emperors such as Nero, Domitian, and Trajan during the first and second centuries CE. A World Heritage site, Hadrian’s Villa covers at least 120 hectares and consists of ca. 30 major building complexes. Located about 20 miles east of Rome, this government retreat was built between 117, when Hadrian became emperor, and 138 CE, the year he died. The site has been explored since the 15th century and in recent decades has been the object of intense study, excavation, and conservation (for a survey of recent work, see [1]).

From 2006 to 2011, with the generous support of the National Science Foundation and a private sponsor, the Virtual World Heritage Laboratory created a 3D restoration model of the entire site authored in 3DS Max. From January to April 2012, Ball State University’s Institute for Digital Intermedia Arts (IDIA Lab) converted the 3D model to Unity 3D, a virtual world (VW) platform, so that it could be explored interactively, be populated by avatars of members of the imperial court, and could be published on the Internet along with a related 2D website that presents the documentation undergirding the 3D model.

The 3D restoration model and related VW were made in close collaboration with many of the scholars who have written the most recent studies on the villa. Our goal was to ensure that all the main elements—from terrain, gardens, and buildings to furnishings and avatars—were evidence-based.

Once finished, the virtual world was used in two research projects. The first project was a NSF-sponsored study of the usefulness of VW technology in archaeological education and research. The second project involved use of the VW for some new archaeoastronomical studies. The purpose of this paper is to report on the results of the second study.

II. HYPOTHESIS TO BE TESTED

A. Earlier Research

Figure 1. Plan of the core buildings at Hadrian’s Villa. Arrow at lower right indicates location of Roccabruna.

Most of the recent publications on the villa have concentrated on archaeological documentation, restoration, formal, and functional analysis. The latest research by our collaborator De Franceschini and her collaborator Veneziano ([2]) combined formal and functional analysis: it considered the alignment of certain important parts of the villa in relation to the sun’s apparent path through the sky on significant dates such as the solstices. In their recent book they showed how two features of the villa may be aligned with the solstices: the Temple of Apollo in the Accademia, which appears to have winter and summer solstitial alignments; and the Roccabruna, which (as first pointed out by [3]) probably has an alignment with sunset on the summer solstice. One must use expressions such as “probably” and “may be aligned” because De

1 NSF grant # IIS-1018512.
Franceschini and Veneziano were only able to confirm the alignment by autopsy in 2009 and 2010 and obviously could not directly make observations during the reign of Hadrian. But because of the precession of the equinoxes, the hypothesized alignment was verified at Roccabruna in 2009 on June 19 (Gregorian calendar), not on the actual solstitial date of June 21 (Gregorian calendar or June 24 on the Julian calendar). In the Temple of Apollo, the alignment was observed on December 19, 2009. It could not be verified at all for the summer solstice since the relevant part of the structure no longer exists. As De Franceschini and Veneziano noted (p. 183), it would take a computer simulation to achieve more precision and certainty. “Seeing is believing.” The purpose of this paper is present our results in using our VW of the villa to test the validity of the Mangurian-Ray and De Franceschini-Veneziano thesis (“M-R DF-V thesis”) for Roccabruna.

B. Plausibility of Finding Celestial Alignments in Hadrianic Architecture

The work of De Franceschini and Veneziano is innovative in terms of research on Hadrian’s Villa. But archaeoastronomy itself has become an accepted field of study in recent decades, and a considerable amount of work has been done in Old and New World archaeology (for an impressive recent survey, see [4]). In Roman archaeology, however, this approach is still rarely encountered. Significantly, one of the few compelling case studies concerns the most famous Hadrianic building: the Pantheon in Rome. Recent studies [5], [6], and [7] have shown a number of solar alignments in the building, of which the most notable are the sun’s illumination of the entrance doorway at noon on April 21; and the view of sunset silhouetting the statue of Hadrian as sun god on a four-horse chariot atop the Mausoleum of Hadrian as viewed from the middle of the Pantheon’s plaza at sunset on the summer solstice. Like the summer solstice, April 21 is also a significant date: on it occurred the annual festival in Rome known as the Parilia (re-named the Romaia by Hadrian [8]), which celebrated the founding of Rome.

C. Reason for Investigating Roccabruna

De Franceschini and Veneziano pursued an observation of [3] to document an impressive example of solar alignment at Hadrian’s Villa involving the feature known as Roccabruna at the western end of the villa. Originally, a tower-like structure topped by a round temple, what remains today is the well-preserved, massive lower floor (figure 2). The main entrance is located on the northwestern side to the right and gives access to a large circular hall covered by a dome. The dome is punctuated by an odd feature: five conduits that are wider on the outside than on the inside (figures 2 [arrow], 3 [labeled A-E]).

What is the function of these unusual conduits? [3] noted that at or near sunset the sun enters through the main door illuminating the niche on the opposite side on many summer days. But the authors speculated that only on the day of the summer solstice in the second century CE did the sun also penetrate into conduit B (figure 3) located above that door: its rays came out from the slot inside the dome projecting a rectangular light blade onto the opposite side of the dome. In June 2009, De Franceschini and Veneziano verified the findings of Mangurian and Ray in an approximate way: the light shone through on June 19. However, they knew that the apparent path of the sun through the sky changes slightly each year, so that in the nearly 1,880 years separating us from Hadrian, the precise effect of the alignment has been lost and cannot be confirmed by autopsy. We therefore attempted to test the M-R DF-V thesis by a computer simulation that uses our virtual world of the entire villa.
III. TECHNOLOGY BEHIND THE SIMULATION: 3D RECONSTRUCTION MODEL, VIRTUAL WORLD PLATFORM, AND SOLAR TRACKER

Before the simulation was possible, we had to build a scientifically accurate 3D reconstruction model of the entire villa in 3D Studio Max, port the 3D Studio Max model to the game engine Unity3D, and create a solar tracker, or virtual heliodon, as a plug-in to Unity3D.

A. Step One: Creation of the 3D Studio Max Reconstruction Model

The reconstruction model relied on the following principal sources: for the plan we used the unpublished AutoCAD plan of Michael Ytterberg, which includes as layers the most accurate previously published plans (e.g., by Piranesi in the 18C, Winnefeld in the 19C, and the geologists of the University of Rome in the 20C) as well as several hundred sheets of an unpublished site survey at scales of 1:50 and 1:100 undertaken under the direction of Robert Mangurian and Mary Ann Ray. In order to ensure that the elevations were the right height, we surveyed the highest point of all standing walls with a Leica Disto D5. This gave us the minimum possible height for most of the complexes on the site, which are in ruins, as well as the precise heights of those still intact (including the lower sanctuary of Roccabruna). For the architecture of the elevations and interiors, we utilized the various monographic treatments of specific building complexes (see, e.g., [9], [10], [11]), and we were fortunate to be able to consult directly with a number of experts on Hadrianic architecture at the villa and elsewhere. We also always gave due consideration to the impressive physical models of the villa made under the direction of Italo Gismondi in 1938 and 1956 (on Gismondi, cf. [12]). The digital terrain map relied on the survey published by [13]. We georeferenced the model with data from Geotiffs licensed from BLOM and with specific points derived from Google Earth and also gathered the site itself with a Garmin Oregon 450t GPS device.

For reconstruction of the gardens, we benefited from the advice of garden archaeologist Elizabeth Macaulay Lewis, whose dissertation [14] included a chapter on the gardens of Hadrian’s Villa. Information about fountains and water features was provided by Jens Köhler as representative of the water studies experts who published [15]. For furniture we relied on [16], whose author also served as one of our consultants, and for sculpture [17]. For restoration of the polychromy of the sculpture we scanned, modeled, and restored, we relied on [18], [19], and [20] as well as personal consultation with experts on specific statues. As supporters of the London Charter for the computer-based visualisation of cultural heritage, we provided the paradata and other documentation for the reconstruction model on a website called the Digital Hadrian’s Villa Project (DHVP).³

³ As of this date (May 1, 2012), the web site is password protected while various requests for permissions from museums are being processed. The site should be freely available to the general public by the fourth quarter of 2012 at http://idialabprojects.org/hvtest/index.php.

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² A valuable online bibliography of research on the villa may be found on De Franceschini’s excellent web site at http://www.villa-adriana.net/ (seen May 1, 2012).
**B. Step Two: Creation of the Virtual World**

Once the 3D Studio Max model was ported to Unity3D, we had to enhance it with avatars to represent members of the imperial court from slaves and guards to the emperor and empress. For the structure and function of the imperial court, we relied on [21], [22], [23], and a special report [24] we commissioned on the court in the age of Hadrian, for which a published monograph is lacking. For the correct dress of the avatars, we followed the advice of costume historian Leslie Yarmo. For the correct gestures to assign each avatar we consulted with Anthony Corbeil and also relied on [25]. Since Unity3D does not support live voice communication between avatars, we linked our executable to C3 of Vivox. \(^6\) An interface was authored in Unity3D to permit easy access to the DHVP website so that users could always see the current state of the site and also understand the basis of the 3D reconstruction they were experiencing.

**C. Step Three: Creation of the Solar Tracking Feature in Unity3D**

Testing the M-R DF-V thesis about the alignment of the lower rotunda of Roccabruna with the setting sun on the summer solstice required that we create a sky dome with a dynamic sun that emitted rays and casts shadows. We therefore programmed a plug-in for Unity3D that controls the movement of the sun on the sky dome in a way that accurately reflects the azimuthal data for the sun in the year 130 CE as seen at the precise geographical coordinates of Roccabruna. The solar tracker, or virtual heliodon, that we created as a response to this research, was envisioned as a simulation that would be a bridge between the virtual environment and coordinates from an external database calculating solar positions.

After investigating existing tools, we decided to employ the Horizons database that was created by NASA’s Jet Propulsion Laboratory as an on-line solar system data computation service – tracking celestial bodies in ephemerides from 9999 BCE to 9999 CE. \(^7\) To implement solar tracking for the villa, we entered the latitude, longitude and altitudes of specific buildings from the Tivoli site to pull the Horizons’ data for the year 130 CE. The Unity3D user interface was enhanced with a slider to change the date of the year as well as a slide to set the time of day. As a user entered new parameters for date and time, the simulation adjusts the sun to accurate coordinates in the sky dome. A “play” button allowed the user to quickly see the sun’s movements over the twenty-four hours of the chosen date. Other buttons allowed the user to jump to specific dates of calendrical significance including

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the two solstices and equinoxes. The system was calibrated to both the Julian and Gregorian calendars (see figure 6).

Figure 6: detail of figure 5c to show a close-up of the solar tracking tool.

IV. RESEARCH OUTCOME

As can be seen in the screen capture of the virtual world of Hadrian’s Villa in figures 5c and 6, the M-R DF-V thesis was confirmed. The figures show a large spotlight of the sun’s light precisely illuminating the statue (figure 5c, arrow B; see figure 6 for a larger view) in the central niche at sunset (18:36 pm) on June 24, 130 CE (Julian calendar).8 The source is the sun radiating light through the front (western) door of the rotunda, just as M-R DF-V thesis predicted. Above the niche, a smaller spot of light (figure 5c, arrow A; see figure 6 for a larger view) illuminates the zodiacal sign of Gemini directly above the statue. The source is the sunlight pouring into the rotunda through the conduit on the western façade of the rotunda, again, in confirmation of the M-R DF-V thesis.

V. CONCLUSION

The tools used in our study allowed for the rapid discovery of potential alignments that might bear further investigation. The tools can be used deductively or inductively. That is, when a theory like the M-R DF-V thesis had already been deduced based on considerations extrinsic to the virtual world, the solar tracking tool could be used to provide empirical proof.

In this sense, it is relevant to note that figure 5b—which presents a 3D Studio Max model and Vray rendering of the scene at sunset on the summer solstice in 130 CE—also attests the correctness of the M-R DF-V thesis. But the figure in 5b is static: it can be changed only on the production side, not by the end user in real time. So the approach utilized to produce figure 5b is only useful for deductive studies.

Alternatively, the virtual world tool presented here can be used in a purely heuristic way to explore the villa with no preconceived notion of what will emerge in the hope that new, hitherto unsuspected alignments may result [26]. The solar tracking tool allows one to proceed inductively, in effect turning the clock back to 130 CE and running experiments in which the days and hours of the year are sped up by many orders of magnitude so that one can in a very short time find candidate alignments not yet hypothesized by scholars working in the traditional way of, e.g., M-R DF-V. We look forward to using the tool this way in future research on the villa.

In moving from deductive to inductive use of the virtual world, some cautions are in order. First, it is important that the claimed alignments be precise, not fuzzy. In the case of the M-R DF-V thesis, there is no doubt but that the predicted solar effect inside the rotunda occurs just at sunset on the summer solstice. If we rotate the camera 180 degrees from its position in figure 5c, we can look out the front door of the rotunda and see the sun just tangent to the horizon to the west. This scene is captured in figure 7:

Figure 7: screen capture of virtual world of the villa with view of the sun setting on the horizon at 6:36 pm on June 24, 130 CE (Julian calendar). Without moving our avatar from the position seen in figure 5c, we have rotated his eyes (i.e., the virtual camera) by 180 degrees.

An example of the danger of imprecision can be seen in figure 8, where the sun appears to be setting on axis at 5:00 pm on April 21, 130 CE:

Figure 8: View of the Pecile, a large colonnaded garden. The imaginary line of the main axis of the built space runs from the back of the avatar in the foreground to the jet d’eau in the background. At 5:00 pm, the sun aligns with the axis of the Pecile on April 21, 130 CE (Julian calendar).

8 The summer solstice of the year 130 CE occurred at 23 hours UT of 21 June on the Gregorian calendar, or Julian day number (JD) 1768714.47. The USNO Julian Date converted gives JD 1768714.46 to be the Julian date June 23 130 CE at 23 hours UT. This is interpreted as June 24 in central Italy by project advisor David Dearborn. Advisor Robert Hannah notes that the Romans defined the summer solstice as June 24 on the Julian Calendar, a date also given by the Voyager software he used to calculate the date in 130 CE.
But as figure 9 shows, the actual sunset occurs at 5:24 pm, at which point the sun has moved off axis of the built space.

Figure 9: true sunset occurring at 5:24 pm on April 21, 130 CE (Julian calendar), from the perspective of someone standing at the east end of the main axis of the Pecile. Note that at sunset the sun is off axis to the right.

Figure 9 also exemplifies another important point: in working with celestial alignments with built features, one must be interested not in the natural, or absolute values of events such as sunrise and sunset but in the relative, positional values as determined by the built features. In the case of the Pecile, the colonnade surrounding the central garden blocks a view of the horizon line. So if a meaningful alignment were to occur here, it could not be with respect to the horizon. Positional sunset thus occurs a bit earlier in this case than natural sunset for the same date.

The example just discussed involves the risk we run in our eagerness to find an alignment which, if true, would obviously be significant. In this case, the date April 21 is culturally important since, as noted above in II.B., each year on that day the Romans celebrated the annual Parilia festival in remembrance of the foundation of their city. The converse cautionary note we should bear in mind is that in looking inductively for alignments, we must reckon with the probability that there are many more random, accidental hits of the sun’s light on built features than culturally significant ones.

How can we distinguish between the accidental and the meaningful? For a culture like that of ancient Rome, the religious calendar can often be decisive in settling this issue. We are fortunate in having fairly complete information about the calendar in the high empire. We know which days were celebrated, and the interpretation the Romans gave to the god to whom it was dedicated, the rites considered normal and which special. For many holidays, we generally know the date April 21 is obviously be significant. In this case, the date April 21 is

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REFERENCES


9 John Fillwalk was primarily responsible for sections III.B and III.C; Bernard Frischer for the rest.


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