1000 years of the Olympic Games: treasures of ancient Greece
The digital reconstruction of Olympia, 3D Zeus and website.

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Figure 1: sculpture detail from the west pediment, Lapith and Centaur. Archaeological Museum at Olympia, Athens. © Hellenic Ministry of Culture. Photo Peter Murphy.

Anyone who has experienced a wild winter storm in the Alpheios valley and seen the sky resplendent with blinding lightning, or who has been startled by a sudden mighty thunderclap on a stifling summer's day, will have no reason to doubt that this isolated part of the western Peloponnese is indeed the most important Sanctuary of Zeus, wielder of thunderbolts and father of the Gods. [1]

Abstract

An exhibition at the Powerhouse Museum, Sydney entitled *1000 Years of the Olympic Games: treasures of ancient Greece* (July 18 – November 18, 2000), offered a unique opportunity to supplement the traditional experience of the visitor by the introduction of virtual reality components.

A team comprised of curators, archaeologists, surveyors and photographers traveled from Australia to Greece to capture the data sets in high resolution using laser scanning and digital photography. This paper addresses both the technical and curatorial aspects of creating this information complex.

The opportunity to record and present this material has been through the generous agreement of the Hellenic Ministry for Culture. Without their full cooperation access to the archaeological material and the some of the most impressive sculptures from the Temple of Zeus that used in the production would not have been possible. Sponsorship to complete the work was generously provided by Intel Corporation (http://www.intel.com.au).

Keywords: virtual reconstruction; ancient Olympia; three dimensions; web site; laser scan; polarised; heritage; zoomable; panoramic.

Introduction

An exhibition at the Powerhouse Museum, Sydney entitled *1000 Years of the Olympic Games: treasures of ancient Greece* (July 18 – November 18, 2000), offered an unique opportunity to supplement the traditional experience of the visitor by the introduction of virtual reality components. The 54 rare antiquities, which travelled from Greece for the first time, were enhanced using a full-scale digital reconstruction of ancient Olympia, and a 3D model of the statue of Zeus from Artemision (a national treasure on permanent display at the National Archaeological Museum in Athens). The Exhibition was further supplemented by a web site that took advantage of the latest delivery

technologies to present both 3D images and high-resolution “zoomable” images in a complex of historical, architectural archaeological, cultural and contemporary data about the site of Olympia.

A team comprise of a curator, archaeologist, two surveyors and a photographer traveled from Australia to capture the data sets in high resolution using laser scanning and digital photography. This paper addresses both the technical and curatorial aspects of creating this information complex.

The reconstruction of ancient Olympia produced a dimensionally and historically accurate model of the site, as it would have appeared in approximately 200 BC. Model detail was achieved through the use of archaeological plans produced by the German Archaeological Institute (dating from 1897) and this was supplemented with additional topographic and survey plans of the site. In addition, surface textures were added to enhance the model in terms of both historical accuracy and aesthetics. The model was produced in stereo and with the use of polarisation the effect of three-dimensionality was achieved to immerse the viewer in the scene. The viewer is then given an interactive tour of the virtual site complemented by 360° panoramas of the present day site (captured in March 2000) at selected positional in the 3D recreated scene.

The digital facsimile of the statue of Zeus was achieved using state-of-the-art 3D data capture techniques. The process of data capture utilised laser scanning to sub-millimetre accuracy enabling the statue to be displayed as an almost exact digital copy of the original. Surface textures were mapped using digital and conventional photography to compliment the spatial accuracy of the model. The model may be viewed with the use of shutter glasses, to achieve a high quality 3D effect. The objective, from a curatorial perspective, was to make the transition from the real objects to the virtual surrogate as seamless as possible for the visitor.

The Exhibition was complemented by an extensive web site that gave access to both these 3D models, and a wealth of object related information and photography. The web site provides supplementary educational material, and resources for exploring the full glory of ancient Olympia.

This paper will demonstrate how the creation of these digital environments offer valuable educational and research opportunities explored through the processes of reconstruction. Such a project presents a unique referencing and archival method that combines complex data sources, extracted and re-created using recent technological advances.

Project description

Exhibition description

Sydney was not only the venue of a special event in the form of the 25th Olympiad; it was also host to the most significant selection of antiquities from ancient Greece ever seen in Australia. Sydney's Powerhouse Museum featured 54 ancient objects - most of them usually on permanent display in their museums of origin in Greece, and many being famous icons of Greek art.

The exhibition, *1000 Years of the Olympic Games: treasures of ancient Greece* (July – November 2000), captured some of the magic that constituted the essence of Olympia, and the vibrant ancient Greek society in which it thrived. The majority of objects coming from Greece to the Powerhouse Museum, including sculpture, grave markers, votive offerings, ceramic vessels and sporting equipment, date from around 700 to 200 BC. This slice of time is one of the most energetic periods of human endeavour ever recorded. Subdivided chronologically for our convenience into the Archaic (about 660-480 BC), Classical (480-323 BC) and Hellenistic (323-27 BC) Periods, it was during this time that the essentials of western life we now take for granted were honed - including philosophy, poetry, drama, architecture, art, and sport.

The site of Olympia is situated in fertile countryside squeezed by the steep and tree covered Mount Kronos into the elbow of two rivers - the Alpheios and Kladeos. Archaeology and historical records show that little has changed at this site over the past few millennia. In the prehistoric period its verdant topography inspired the worship of nature gods, and set it on a course for greatness as one of the glories of ancient Greece. This isolated glade was to spend 1000 years as one of the most important religious sanctuaries in Greece, with its Olympic Games a fundamental component of worship to the supreme deity in the ancient Greek pantheon: Zeus [2].

Existing reconstructed models (3D)

A number of existing reconstructions were researched before work commenced. A rich historical site, of much archaeological and cultural significance, Olympia has been the basis of a number of digital reconstruction attempts. In particular the Temple of Zeus and Zeus have received considerable attention. Models are included on the web sites such as:

- http://devlab.dartmouth.edu/olympic/site/vrindex.html
- http://unmuseum.mus.pa.us/ztemp.htm

Excellent digital reconstruction has also been completed by the Foundation of the Hellenic World (http://www.fhw.gr/fhw/en/projects/3d.html) but this work has not yet included an adequate model of the Temple of Zeus. None of the existing models were considered anywhere near the quality that we required for the web site, let alone for the exhibition installation. A digital dataset, therefore, did not exist.

Aside from these digital models three built scale models exist. Two of these are housed in the foyer at the Archaeological Museum at Olympia (one constructed by German archaeological teams, and one by the Museum itself), and another model set in 100 BC at the British Museum in London. This latter model is not on display but extensive medium format photographs gives good reference to the topography and structures that could be used as a reference for reconstruction.

Data acquisition

A considerable component of the overall project has been the acquisition and analysis of source information, especially as a high degree of veracity and verisimilitude was required. The digital reconstruction process attempted at all time to create an archaeologically correct interpretation of the research materials available.

Archaeological and historical sources

The site of Olympia

The site of Olympia is located between the Cladeus and Alpheios rivers and the beneath the hill of Kronos. Most of the archaeological remains are scattered across the site, the result of two earthquakes of the 6th century AD and numerous floods. Those foundations that survive date to different periods, from the Archaic, Classical, Hellenistic and Roman times.

The excavations at Olympia were begun in May 1829, by French archaeologists. The initial finds (metopes from the opisthodomus and parts of the metopes from the pronaos of the Temple of Zeus) were transferred to the Louvre where they are still being exhibited. When the Greek government was informed of the looting of artefacts, the excavation was stopped.

Excavations were started again 45 years later by German archaeologists. The research continues today by the German Institute of Archaeology in Athens, and the Ephorate of Antiquities in Olympia. The Museum of Olympia associated with the archaeological site houses many of the sculptural and object material that has been recovered from the site. Supplementary material on the archaeological site and its associated Museum can be found on the Hellenic Ministry of Cultures' web site (http://www.culture.gr/).

The bibliography on Olympia runs to hundreds of items, although those dealing strictly with the archaeology of the site can be counted in the mere dozens. The most important sets of documents for the reconstructions were some of the oldest. It almost goes without saying that any work on Olympia would be nearly impossible without Pausanias' *Guide to Greece* [3]. There may be quibbles with the detail of different translations but that is irrelevant given the scale of this project.

The five text volumes of the earliest German series, *Olympia. Die Ergebnisse der vom Deutschen Reich veranstalteten Ausgrabung* (F. Adler et. al. 1892-1897; referred to hence as the Adler and Curtius publications [4]) contain incredibly detailed descriptions of buildings and objects, complemented by the hundreds of plans, sections, drawings and reconstructions in the accompanying folio volumes. Subsequent important updates have been published by Ashmole & Yalouris 1967 [5]; Grunauer 1971 [6] and 1981 [7] ; Miller 1971 [8]; Mallwitz 1972 [9]; Herrmann 1972 [10]; Koenigs 1984 [11].

Fieldwork

a. The statue of Zeus

One of the most significant sculptures in the National Archaeological Museum in Athens is the statue of Zeus from Artemision (Artemesium), also considered to be perhaps a statue of Poseidon. This bronze sculpture is slightly larger than life size, and was found in 1926 in the sea off Cape Artemision. It is one of the few surviving examples of Early Classical statuary.

A Modelmaker Laser Scanner mounted on a Faro 3D Coordinate Measurement Arm was used to create high-resolution point clouds of the surface of the statue. A purpose built scaffold was

fabricated in Athens to enable elevation of the scanner to the top of the statue while ensuring a stable fixture. The entire sculpture was digitised over several daytime sessions in multiple parts. There were considerable restrictions on this part of the project, which included no method or re-orienting the scanning system datum and a very short working period in the Museum. This created complications in the data stitching process (refer to Zeus Data Refinement below). Figure 2 and 3 illustrate the scanning process.

Figure 2: laser scanning the statue of Zeus at the National Archaeological Museum in Athens, March 2000. © Hellenic Ministry of Culture. Photo University of Melbourne.

Figure 3. laser scanning the statue of Zeus at the National Archaeological Museum in Athens, March 2000. © Hellenic Ministry of Culture. Photo University of Melbourne.

b. Field survey at the site of Olympia

The topography of the site and the locations of key structures were also surveyed by members of the team so that the present surface (which approximates the original ground level of the site) could be used in the visualisations. This was performed using surveying equipment loaned by the National Technical University in Athens. A digital elevation model was prepared from this data, and combined with a detailed terrain model of Kronos Hill obtained from large-scale topographic maps. In addition, the surrounding landscape was also modelled from smaller scale topographic series maps. As a result, the landscape of ancient Olympia used in the visualisations is a very close approximation to the terrain of the period.

c. Field photography at the site of Olympia

Twenty-nine positions were surveyed in, placed strategically around the archaeological site. From these positions high-resolution panoramic images were taken using an 185° fish eye lens mounted on top of a 25-foot pole. Four photographs were taken from each position and later stitched together. The panoramas were then incorporated within the digital reconstruction.

Figure 4: flatten panoramic photograph taken at the site of Olympia, March 2000. © Hellenic Ministry of Culture. Photo Peter Murphy.

d. Sculptures from the Temple of Zeus, at the Museum of Olympia

The central room at the Museum hosts one of the most impressive works of art from the early Classical period, executed in the severe style, created and put in place about 456 BC. These were the metopes depicted the 12 labours of Hercules, and the east and west pediments all from the Temple of Zeus. There is conflicting scholarship as to the reconstruction and placement of the pieces as further outlined below.

There were 42 figures decorating the 2 pediments of the temple, 12 metopes and the lion-headed water spouts running along the lengths of the temple. It is one of the best surviving ensembles from ancient Greek works of art. They belong to the "austere style" and date to the 1st half of the 5th century B.C.

The eastern pediment depicts the chariot race between Pelops and Oinomaos, and the central figure, which dominates the work, is of Zeus. The western pediment depicts the abduction of the Lapith women by Centaurs, and has Apollo as its central figure. The metopes bear the relief representation of Hercules' labours. These sculptures were made during the 5th century B.C.

Figure 5: Sculptural detail from the Temple of Zeus The Centauromachy. Archaeological Museum at Olympia, March 2000. © Hellenic Ministry of Culture. Photo Peter Murphy.

A set of high-resolution images was made of the material in the Archaeological Museum at Olympia. These comprised of panoramas of the exhibition space and object models (with up to 15 overlapping photos per statue) of each of the figures represented in the pedimental sculptures.

Reconstruction and model making process

Archaeological and historical considerations

It was decided to attempt to reconstruct Olympia, as it had been around 200 BC. Of course, it is actually impossible to pick a single year to reconstruct an ancient site, given the relative coarseness

of archaeological chronology. At a site like Olympia, used without interruption for over a thousand years, almost certainly with frequent refurbishment of quite old buildings, it is really only possible to establish the rough date a building was erected. Whether a building was undergoing renovation in a particular year cannot be stated. The length of time it took to complete buildings is also another issue.

The choice of 200 BC was therefore made for mainly practical reasons: the later the date in the site's history, the more buildings there would be, and the more interesting a virtual tour would be for modern visitors and would more closely correspond with the extant ruins; it was an Olympic year; it was just before the Roman annexation of Greece began; and there is a nice resonance with 2000 AD for the overall link with the exhibition with which the tour and web site are associated. The date was stretched slightly in order to incorporate the entire gymnasium and the *krypte* entrance to the stadium.

An over-riding philosophy was to attempt to recreate the atmosphere of the site, and particularly to avoid the clean, almost plastic textures of many digital buildings.

Supporting documentation for the basis for reconstruction is also contained on the web site, directed at an interested lay audience.

a. Individual buildings

The Adler and Curtius publications provided detailed ground plans of most buildings. As well, the elevations were usually calculated, and the extant decorative elements, mainly terracotta *simae* and *akroteria*, were associated with each building. Major additions or changes to some buildings were taken from the later publications. The drawings were used directly by the modellers to recreate each building. An attempt was made to incorporate as much small detail as possible given the limits of time and computing power (both in rendering and delivering the animated tour). For example, the Adler and Curtius volumes contained the differing capitals and columns of the Heraion, and these were included in the model.

Inevitably, there was missing information and the limited timeframe meant that not every known detail could be incorporated. The application of colour, which is now standard in our concept of ancient Greek architecture and art, is still difficult because of the lack of evidence. One particular difficulty in using the early German work is that the colour plate published (Volume II, plate CXII [13]) does not correspond with the text description of colours or placement, even though it is supposed to be the template for the painting of Doric buildings at Olympia. This is partly a factor of colour printing techniques in 1896 and the fact that we had the 1966 reprint, and also due to the difficulty of really knowing what colours such as "mild whitish cobalt blue" or "a strong but at the same time transparent blue" actually were. However, we followed the Adler and Curtius publications as closely as possible in terms of applying colour to the buildings, and the evidence of the terracotta roof decorations excavated at the site was particularly helpful in this regard.

Buildings which must have had pedimental sculpture or for which some fragments of sculpture remain, such as the Metroon, were given pale blue pediments, rather than attempting a poor reconstruction. Doors and lattice screens were based on those depicted on black and red figure vases.

Probably the least satisfactory outcome, given the time restrictions on the project related to addition of statuary to the Altis area of Olympia. Literally hundreds of dedicatory statues and objects would have been crammed into the sacred area, but we were only able to reconstruct a handful, modelled on excavated statue bases and the descriptions in Pausanias.

Our most ambitious reconstruction was the interior of the Temple of Zeus. This was based only on Pausanias' descriptions as no evidence remains. It is thought that some coins and Christian icons reflect the seated Zeus figure, once one of the wonders of the ancient world, but they have already past through the filter of later cultural biases.

For the web site reconstructions of the Temple of Zeus sculptures, we planned monochrome reconstructions, and an attempt at colour reconstructions of the metopes only. To avoid confusion for the web site visitor, our reconstruction of the central group of five on the east pediment was arranged to reflect the placement in the Museum. The academic alternatives to the placement of figures are discussed in the project documentation (refer to the web site).

Colours for the metopes (for example Figure 6) were based on the German publications, ancient terracotta statues excavated at Olympia, and contemporary Greek red-figure vase painting.

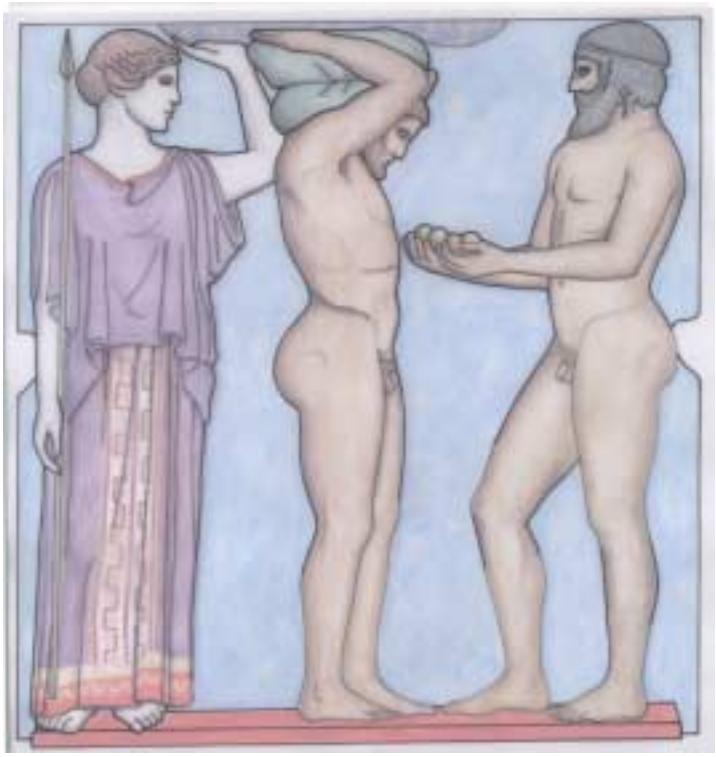

Figure 6: Colour interpretation, The Apples of the Hesperides. Metope X. Drawing David Loong.

Zeus data refinement

The data resulting from the laser scanning operation consisted of very dense clouds of points representing the surface of the statue with a coordinate accuracy of around 0.2mm. This presented many difficulties as the data sets were huge and needed substantial filtering before they were useful. The decimation process reduced the density of the data points without reducing the high level of detail in the model. The process used a variety of software packages, finally resulting in a 3D Studio Max model of the statue. This contained over 2 million polygons.

The material maps for the surface need to be acquired separately as the laser scanner only acquired shape data. The restriction on photography in the Museum meant that few opportunities arose to acquire images of the statue. Eventually digital video was acquired and this has been used as the basis for the true surface material.

Figure 7: partial animation series for the statue of Zeus from the National Archaeological Museum, Athens, March 2000. © Hellenic Ministry of Culture. Photo University of Melbourne.

Figure 7 shows 3 frames from a work-up animation sequence of the face of the statue and a render of part of the statue to show the level of detail.

Digital reconstruction of Olympia

The reconstruction of ancient Olympia was a long and involved process. At all times effort was made to create models and materials that were not only visually appealing but also historically correct (using the sources outlined above).

The original building models were created in Bentley System's MicroStation CAD package, primarily because of the level of experience with this package and its suitability for precise dimension control. This choice however caused many difficulties when translating data into the 3D modelling package used, the only common workable export format was DXF which not only gave considerable errors in relative position of elements but also created very large polygon counts for even simple objects. Much of the building elements were therefore re-created in 3D Studio Max from scratch.

Every graphic element was created for the project. Existing digital Greek architectural elements would not have allowed us to maintain a sufficiently high level of contextual accuracy. For example, the Temple of Hera (where the Olympic torch is ignited) has every column different as it was constructed and reconstructed over a long period of time. Standard commercial library elements did not easily modify, in all cases it was easier to create new elements. The human figures and statues were modelled originally in Poser V4, and modified in 3D Max.

Figure 8: work in progress, rendering the Pryaneion. © Hellenic Ministry of Culture.

Figure 9: work in progress, rendering the Pryaneion. © Hellenic Ministry of Culture.

Figure 10: work in progress, exterior view east end of the Temple of Hera. © Hellenic Ministry of Culture.

Figure 11: work in progress, view from inside the Palaestra. © Hellenic Ministry of Culture.

All of the animations were created using 3D Studio Max V3. Consideration was given to using a variety of other packages however the render-farm facility of 3D Max offered substantial (essential) time saving. The render-farm finally consisted of approximately 60 machines, ranging from very fast PIII to PI computers. While the render-farm required nurturing the process greatly facilitated the delivery of the exhibition in a very short time period.

Once the high-resolution model of the entire precinct had been completed, proxy buildings were developed for all of the structures to facilitate rendering scenes where background buildings were not required in high 3D detail. Once again, this was essential in reducing the rendering time. The texture maps for the proxy buildings were derived from renders of the high-resolution models.

The rendering consisted of a number of animation sequences (unknown at time of writing) timed to fit the narration. These were created as single frames for later composition and post-production.

Delivery mechanisms

3-D Zeus

The Zeus model was presented in a separate virtual reality booth at the Exhibition. It was displayed using shuttered glasses technology (they were suspended from the roof), driven by proprietary software running on Intergraph hardware. The use of shuttered glasses necessitates the presence of a museum attendant; this option was not pursued for the reconstruction of Olympia because of inherent staffing requirements, which used polarised projection.

A limited amount of interactivity was provided where users could rotate the model about its vertical axis, and zoom in and out. A higher degree of interactivity was not appropriate given the respect accorded the actual object itself, and indeed therefore its facsimile!

Digital reconstruction of Olympia

The delivery of the VR reconstruction posed many challenges. The intention was to provide a 3D ‘experience’ of Olympia to an audience of up to 20 people at a time using affordable technology. A rear-projection polarised projection system with inexpensive plastic glasses was developed so that there was not need for a Museum attendant to be present in the virtual reality room.

a. The Virtual Reality Room

Two JVC DLA-C15 rear projection capable projectors were used to overlap the left and right channel images onto a 2.8m wide screen in a 25m square room. A custom built console was designed to facilitate user interaction at the decision points, and mounted on a stand approximately 3m from the screen.

The computer used to deliver the movies was an 800MHz Pentium III machine, with 500Mbyte of RAM, fast disk access and a Matrox G400 graphics card. This card has a twin screen output of 800x600 resolution, which was used to drive the two projectors.

The projectors were located in an air-conditioned alcove behind the projection screen, and mounted so that the two images exactly overlapped on the rear projection screen.

The audio was delivered using a Soundblaster Live audio card with 2 front speakers with a subwoofer all mounted behind the screen.

b. The Virtual Reality Experience

From the outset it was decided that the visit to ancient Olympia would be a memorable experience, offering visitors the opportunity to both be entertained and educated by the exhibition, and 3D stereo facility offered an excellent platform on which to develop the content. It was decided that an affordable solution to 3D projection would be used to deliver a narrated tour through the ancient Olympia visualisation, with visitors being able to decide at certain points which direction the tour should take. Inexpensive polarised glasses were mode available in the projection room, and the navigation device was obvious and robust.

The 3D experience offered to visitors was developed in Macromedia Director using a stage that was 1600x600 pixels. Two 800x600 animations sequences were placed side by side in the movie ensuring very close synchronisation between the left and right eye channels.

When the room was empty, a 'teaser' (or screen saver) appears giving an indication of what was contained in the exhibition. When any console button activated the display, an introductory sequence plays instructions on how to navigate the city; to wear the glasses; and how to access other facilities on the tour. Then the first sequence in the tour is presented up until the first point where visitors make a decision on which component of the tour to undertake next. At this point navigation aids appear on the screen, and the tourists then activates their decision by choosing a certain button on the console. The relevant sequence is loaded from disk and played through the projectors. Use is made of still frames to allow the large animation sequences to be read off disk and played without the appearance of delay.

The tour through the site was designed both to exploit the beauty of the reconstructed buildings and to allow sufficient time to have the story of the site told. Curatorial principles common to conventional museum exhibits were used to develop the tour path and the script of the narration. The length of the audio sequences was used to time the animation sequences, with pauses in the visual component being added in the composition stage to keep the two in synchronisation.

Website (http://www.phm.gov.au/ancient_greek_olympics/)

Figure 12: screen grab from the homepage of the web site, http://www.phm.gov.au/ancient_greek_olympics.

The production of a state-of-the-art web site (http://www.phm.gov.au/ancient_greek_olympics/) was able to combine the datasets from the digital reconstruction of Olympia and the 3D Zeus (presented as an anaglyph and uploaded as a Metastream object viewed using downloadable glasses), with a panoramic tour of the Exhibition itself and including the displayed objects. Also on the web site, all the sculptural details from the Temple of Zeus are displayed as high-resolution zoomable images (using ZOOMIT by MIGSoft). The images of the metopes are supplemented with reconstruction drawing and coloured overlays that drew on archaeological research. Access to the panoramic photographs of the present day site (29 panoramas with full screen viewing option) is driven by an interactive map of the archaeological site.

A detailed section of the archaeological site plan is shown in Figure 13. Positions for each of the panoramic photographs within this map were later shown on the interactive display on the web site.

Figure 13: section of the archaeological plan made of the site of Olympia by the Germans archaeologists, 1897.

Virtual panoramas of the digital model were included as .ivr movies in Live Picture format selected from locations that corresponded with the panoramic photographs.

The web also allowed for supplementary datasets including extensive essays (in PDF format), and audio files, to be downloaded. The complex genealogy of the ancient gods was converted into a nodal web map.

The web site has a projected life of two years at least, and forms part of educational and research materials available through the Powerhouse Museum Internet resources.

Conclusion

Virtual reality models allow us to put a number of data sources and formats available about a site/ or object into a user-interactive product. Quite apart from the popular impact these models have, they enable us to test and refine the complex data in a highly visual format.

The web site was able to extend the brief of the Exhibition itself to offer not only the 3D objects but also much supplementary data (eg pedimental sculptures and metope overlays, panoramic views of the present day archaeological site) that far exceeded what the Exhibition could present. And despite the large number of visitors to the Museum, the online component had an estimated hit rate of 5 million per week during the Olympic period. The web site gives longevity to the scholarship that formed the Exhibition, and spawned a great deal of research that will stand as an academic resource in is own right.

Future uses and research potential for the VR model

- Modelling sun in relation to temples.
- Modelling the earthquake effect on the Temple of Zeus.
- Model allows for further research sanctuary usage and liturgical practise.
- Choices for colour applications invite responses from the academic community.

References

[1] K. Herrmann, Olympia. The sanctuary and the contests*, Mind and Body,* Exhibition catalogue, Athens, 1989.
[2] P. Donnelly, comments from the curator, *1000 years of the Olympic Games: treasures from ancient Greece,* Powerhouse Museum, Sydney, Australia, 2000.
[3] Pausanias, *Guide to Greece vol 2: Southern Greece* (trans. P. Levi), Penguin Classics, London, 1979.
[4] *Olympia. Die Ergebnisse der vom Deutschen Reich veranstalteten Ausgrabung*, volumes I-V:
F. Adler, E. Curtius, W. Dörpfeld, P. Graef, J. Partsch & R. Weil
Olympia I: Topographie und Geschichte, Verlag Adolf M. Hakkert, Amsterdam, 1897/1966.
R. Adler, R. Borrmann, W. Dörpfeld, F. Graeber & P. Graef
Olympia II: Die Baudenkmäler von Olympia, Verlag Adolf M. Hakkert, Amsterdam, 1892/1966.
[5] B. Ashmole & N. Yalouris & A. Frantz, *Olympia: The Sculptures of the Temple of Zeus*, Phaidon Press, London, 1967.
[6] P. Grunauer, "Der Zeustempel in Olympia – Neue Aspekte", *Bonner Jahrbuch*, 171, 1971, pp 114-131.
[7] P. Grunauer, "Zur Ostansicht des Zeus Tempels" , *X. Olympische Bericht*, 1981, 256-301.
[8] S. Miller, "The Prytaneion at Olympia", *Ath. Mitt (AM*), 86, 1971, 79-107.
[9] A. Mallwitz, *Olympia und seine Bauten*, Prestel-Verlag, Munich, 1972.

[10] H.-V. Herrmann, *Olympia: Heiligtum und Wettkampfstätte*, Hirmer Verlag, Munich, 1972.
[11] W. Koenigs , *Olympische Forschungen XIV: Die Echohalle*, Verlag Walter de Gruyter & Co/DAI, Berlin, 1984.
[12] *Olympia. Die Ergebnisse der vom Deutschen Reich veranstalteten Ausgrabung*, volumes I-V:
F. Adler, E. Curtius, W. Dörpfeld, P. Graef, J. Partsch & R. Weil
Olympia I: Topographie und Geschichte, Verlag Adolf M. Hakkert, Amsterdam, 1897/1966.
[13] R. Adler, R. Borrmann, W. Dörpfeld, F. Graeber & P. Graef
Olympia II: Die Baudenkmäler von Olympia, Verlag Adolf M. Hakkert, Amsterdam, 1892/1966.

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The web site was conceived by the Powerhouse Museum with graphic design by Massive Interactive (http://massive.com.au). The photographic work at the archaeological site was undertaken by Peter Murphy, Sydney. It is his genius also that enabled much of the data that is displayed on the web site. The overlays for the metopes were draw by a meticulous and hardworking David Loong.

The sonorous tones of David Rutledge were recorded for the tour and used for a number of audio files on the web site.

The digital reconstruction was developed by a team of real people. Thanks also go to Lefki Pavlidis for her assistance with the data collection and laser scanning in Greece, and to Vu Nguyen and Asher Graham of Osmosis for the ability to work long hours with such cheer and ability in order to produce the virtual Olympia.

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Figure list

Figure 1: sculpture detail from the west pediment, Lapith and Centaur. Archaeological Museum at Olympia, Athens. © Hellenic Ministry of Culture. Photo Peter Murphy.
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