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DIGITAL CULTURAL HERITAGE: APPLICATIONS OF 3D COMPUTER GRAPHICS IN RECONSTRUCTING THE LOST REALITY OF THE TEMPLES OF IONIA

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Abstract

Reconstructions of the past with the advent of 3D computer graphics and high resolution rendering are increasingly produced and maintained in digital form, thus creating a legacy: Digital cultural heritage. Digital cultural heritage requires serious attention and is the subject of this paper. The reconstruction of the lost Ionic temples of the western shores of Aegean Sea is the main focus. The history of their construction, destruction and reconstruction loops are traced. The exceptional architects who had worked out the style and the principles of construction are looked into. Superstructures they created are studied with the aid of the accounts of the ancient writers, fragments in museums and surviving portions. Finally, their 3D reconstructions are realized so far as possible.

Keywords*: Digital cultural heritage; 3D computer graphics; reconstructing the lost reality, Ionic temples.*

1. INTRODUCTION

The cultural heritage which holds a significant part of the intellectual

wealth of our information society is under increasing threat of demolition. The threats of destruction stem not only from the natural causes, but even more so from local and international dissents and conflicts. Damage by Taliban of the 1700 years old sandstones of Buddha in Afghanistan, and looting of the historical city of Palmyra in Syria are just two examples of the cultural properties imperiled. With their destruction and disappearance of irreplaceable evidences of ancient life and societies are lost to posterity.

3D Computer Graphics, through technological innovations, offers an ability in 'reconstructing the past' beyond those originally imagined. Considering that the disappearance of heritage is an impoverishment of the intellectual wealth of all nations, the use of this capacity of 3D computer graphics in archaeology and cultural heritage entices careful consideration.

Starting from the beginning of 90's the use of 3D computer graphics in relation with archaeology and cultural heritage has been a focus of attention for scholars in multi-disciplinary fields. An abundance of publications have emerged in the last two decades which have presented photo-realistic reconstructions of the past. "Virtual archaeology: Re-creating ancient worlds" is the evocative title of the book edited by Maurizio Forte and Alberto Siliotti in 1997 [1]. Experts from different parts of the world had collaborated in that book which provided with 660 illustrations a virtual journey to the cultural heritage sites of the world.

This stream continues to make contributions to the creation of a new legacy in cultural heritage. Reconstructions of the past with the advent of 3D computer graphics and high resolution rendering are increasingly produced and maintained in digital form, thus creating a legacy: Digital cultural heritage.

Digital cultural heritage requires serious attention and is the subject of this paper. The reconstruction of the lost edifices of the eastern shores of Aegean Sea is the main focus of the paper. The Ionic order of architecture had reached its culmination with the building of four great Ionic Temples on the Eastern coast of the Aegean Sea. They were the fruits of the great temple-building epoch which was started with the building of the Great

Temple of Hera at Samos in the first half of the 6th century B.C. This period had passed with the end of the 5th century B.C., but the recurrence of fires caused by arsonists, rioters and invaders demanded reconstruction of the demolished structures. In this paper, the history of their construction, reconstruction and destruction are traced. The exceptional architects who had worked out the style and the principles of construction are looked into. Superstructures they created are studied with the aid of the accounts of the ancient writers, fragments in museums and surviving portions. Finally, their 3D reconstructions are realized so far as possible.

2. RECONSTRUCTING THE FOUR GREAT IONIC TEMPLES

The four greatest Ionic temples of the world had reigned in the same geographical region. Three of these were built on or near the Aegean coast of Asia Minor. The other one was on an island separated only by a narrow strait from the mainland. Together they revealed elegance and supremacy which were difficult to surpass by any architectural achievement in any other part of the world. These are the Temple of Hera at Samos, the Temple of Artemis at Ephesus, the Temple of Apollo at Didyma and the Temple of Artemis at Sardis.

Colossal temples of Ionic order were built in the archaic period when the Ionians were at the peak of their golden era. The earliest of these was the Temple of Hera at Samos (The Heraion). This temple Herodotus compares with the labyrinth of Egypt and the temple at Ephesus for extent and magnificence and states that it was the largest he had seen. The temple at Ephesus which was seen by Herodotus was Archaic Artemision, the second of the four great temples. This building was burned on the night Alexander was born (356 B.C.). Yet to be built again with more splendor and grandeur (Classical Artemision). It was adored as one of the seven wonders of the ancient world. It is intriguing whether Herodotus would not change his opinion had he lived after the time of Alexander and seen the last form the Artemision took. According to some the third temple in Didyma (the Didymaion) excelled both the Heraion and the Artemision, and it was with

the fourth temple at Sardis the antiquated Doric order was put in shade.

The designer of the Heraion was Theodorus (together with Rhoikos). The archaic temple at Ephesus was also designed by Theodorus (together with Chersiphron and Metagenes). The architect of the classical temple at Ephesus was Paeonius, he was also the architect of the temple at Didyma. With this line of continuation from temple to temple Ionic order emerged and evolved along the eastern coast of Aegean Sea into an architectural style whose grace and magnificence continues to fascinate the beholders.

These four colossal dipteral buildings shared common destiny, they were all destroyed by fire. New buildings were built to replace the old ones. In each case the newer buildings were designed on colossal scale because the older buildings had been colossal. Their lines were determined by the lines of the older temple.

The Heraion and the Artemision were stripped bare to the level of stratum. The Didymaion and the Temple of Artemis had been left with a few pillars standing. Anyone who today stands before the excavation areas of these temples finds it very difficult to reconstruct in his mind a picture of these buildings. But by comparison and analogies between the general schemes of these temples indirect evidences can be obtained which lead to their reliable reconstruction.

The aim of this paper is twofold. Firstly, it sets out to bring a formal and unified approach to these four great Ionic temples. Secondly, it attempts to reconstruct them as if they are standing unharmed and in their original state. In showing vividly how ruined buildings once looked; Reconstruction work can be equally instructive in clarifying how such buildings could not have looked.

3. THE GREAT TEMPLE OF HERA

The Great Temple of Hera at Samos (Heraion) is the first example of the Great Ionic temples. It was a colossal dipteral temple, described by Herodotus as the largest he was acquainted with. Built shortly before the

middle of the sixth century B.C (ca. 570-560 B.C.), Heraion is dated to be earlier than Temple of Artemis at Ephesus (Artemision) by a decade or two. It is widely accepted that this temple together with the Ephesian Artemision established the patterns of the Ionic order which would follow in subsequent years. Cut off only by a narrow strait from Asia Minor, the Island of Samos homed the Greek Ionian citizens of one of the richest and most powerful states in the 6th century. When the thriving community of Samos decided to build a sanctuary of greater monumentality to befit their goddess Hera, the task was given to two great masters named Theodorus and Rhoikos. They dared to take on a Temple of gigantic proportions, the largest ever executed in the Greek world. The accomplishment of the task laid the foundations of the Great Ionic Temples which would follow in Ephesus, Didyma and Sardis.

The sanctuaries which had been built at the same location showed a conspicuous chronological progress. They were all dedicated to Hera who was born in Samos according to mythology. Comparison of them side by side provides a better grasp the magnitude of the 6th century temple (Theodorus Temple). The plan of the Theodorus Temple displays a vast leap in proportions.

The upsurge which this temple had brought to Greek temple architecture was not confined to size, though. The former buildings were known as Hekatompedons meaning " hundred-footers" . They were all built out of wood and mud brick, and trunks of large trees were used as columns. Theodorus Temple was constructed out of stone.

Theodorus Temple is appropriately credited with "firsts"- the first gigantic sanctuary in Greek world- the first huge stone temple– the first Ionic monument of colossal size- the first dipteral temple, that is why, it is also called Dipteral

The architects had to face up to problems more difficult than they had ever tackled before. How could the foundation be laid on ground which could carry so heavy a load? The problem was exacerbated by the ground which was itself a marsh.

The architects themselves as well as the building must be taken into account in order to better understand how this unusual project came about and developed. Who were these architects who dared to take on a temple more immense than anybody had built, with a material that nobody had ever used so extensively and with problems of engineering that nobody had solved before?

Theodorus and Rhoikos were named in Ten Books on Architecture of Vitruvius [2] as the architects of the Heraion of Samos. The list of achievements with which these architects are credited cover a large scope. These two versatile masters commanded fields of art, architecture and engineering.

Theodorus and Rhoikos were also mentioned in the works of Pliny, Pausians and Herodotus. Some of the works on which the fame of Theodorus and Rhoikos rested are given by Murray [3], and Hahn [4] as follows:

1. Invention of a new technique for casting life-size sculptured statues in bronze.
2. Invention of a new technique for modeling in clay (mentioned by Pliny)
3. A Large bronze vase placed in the Temple of Hera.
4. A silver vase at Delphi made by Theodorus (mentioned by Herodotus)
5. A seal made by for Polykrates , Tyrant of Samos.
6. A great silver vase made by Theodorus for Kroesos.
7. A bronze statue made by Rhoikos for Ephesus (mentioned by Pausians)
8. Theodorus invented a device for securing a straight line.
9. Theodorus invented a lathe in order to automate the production of Heraion’s limestone column drums.

Theodorus is also credited for diverting the river Imbrasus in order to set the platform for the Heraion.

Diverting the river Imbraus was an extraordinary feat of mathematics as well as engineering. Theodorus shared the same epoch with Pythagoras and acquired the mathematical skills from the Samian school of Mathematics. Theodorus's skills as an architect compounded with his skills in engineering and mathematics enabled him to divert the river Imbrasus.

With Theodorus' project land was reclaimed for setting of the platform measuring 105 by 52.5 meters. This was three times the size of its predecessor's platform. The wooden columns of the earlier constructions were replaced with stone columns. The column heights attained almost three times the height of the contemporary doric columns (height of about 18 metres). They stood on bases which consisted of two members. The lower part is the drum which slightly curves inside, the upper part is a torus with a convex profile. Both parts were horizontally fluted which followed different patterns on every base. Standing on these distinctive Samian bases, the colossal columns surrounded the cella in double rows. The double row of surrounding columns was not executed before.

The capitals were out of wood. Not a trace survives of these capitals. This very fact is a consequence of the fact that they were made of wood. The 'advanced wood' technique of the Samian masters gave the ionic capital its distinctive form. The canonical form of the Ionic capital took its characteristic shape in Samos and that form was established after its adoption in the Temple of Artemis at Ephesus. Other monumental temples like the Temple of Apollo at Didyma and the Temple of Artemis at Sardis followed.

This miraculous temple, the first of the Ionia's great temples was destroyed by fire. The cause of the fire was reported by Pausians as Persians. But as the dating of the remains suggests (538 B. C.), it is more likely to be due to internal disturbances which brought Polykrates to power rather than the Persian Wars [5], [6]. Polykrates started on a new temple

right after he came to power which is known as Polykrates Temple or Dipteros II, but it was never finished.This temple which marked the beginning of the great temple building epoch in the Ionic world was the creation of two exceptional men. Of these two, Theodorus was also the first of the ancient master builders whowrote a prosetreatise, now lost but cited by Vitruvius. He had earned a unique fame and position as would encourage the rival Ionian cities to enlist his services. Theodorus was invited by Ephesians for the construction of the second of the sequence of the great Ionic temples.

4. THE TEMPLE OF ARTEMIS AT EPHESUS

Being almost directly across from Samos on the Aegean coast of Asia Minor, the Ephesians would not like to stay in the shade of Samians. Ephesus rivaled Samos by giving start to the construction of the second of the great Ionic temples. They invited Chersiphron and his son Metagenes from Crete and Theodorus from Samos as architects. With the involvement of Theodorus, principles of style and construction of Ionic dipterals which were first worked out in the Heraion were modified and refined. Theodorus together with Chersiphron and Metagenes, one or two decades after the Heraion, took the great archaic age of creativity to its zenith with another Ionic dipteral of colossal size: the archaic Artemision. This temple gave the Ionic style such classical character, distinction and aesthetics that it put the Doric order in shade. In many ways the archaic Artemision was a continuation of the Heraion, but in every aspect it was more lavish and mature.

With its magnificence and beauty the archaic Artemision stood from 550 BC to 356 BC as a source of admiration and inspiration. ‘The archaic Artemision’ writes Jenkins, ‘ until its destruction in 356 BC, stood sentinel over a grand tradition, and its particular form of the Ionic order was to be the one most commonly imitated [7].

The first source of information is Herodotus, from whom we learn that Kroesus (king of Lydia) was the central personality in the creation of the

archaic temple.However, They were known to Vitruvius, Vitruvius' book gives information about the size, number and heights of the columns etc.

Another primary literary source of information is Pliny who had seen the later temple.Just as Ephesus rivaled Samos, in the same spirit of rivalry, Chersiphron and Metagenes also wrote and made public their prose treatise. According to Hahn motivation for writing these prose treatises stemmed primarly from claiming victory in monumental achievement. They had every reason to have the emotions of a victor, since they managed to erect the largest building in the Greek world. It was also the first monument to be built entirely of marble. Having compiled an account of their work Theodorus, Chersiphron and Metagenes started a tradition of writing architectural treatises which continued down through the Hellenistic period. Deinokrates of Ephesus wrote on the later temple.

It is much to be regretted that neither of these treatises survives. However, they were known to Vitruvius. Primarily our knowledge of this temple comes from Vitruvius whose information must have been derived from these treatises which probably included a description of the building both in terms of size, number of columns, etc. Another source of information is Pliny who had seen the later (Classical) temple.

The temple was discovered by English Engineer John Turtle Wood [8] in 1869 after 6 years of efforts. In his excavations remnants of two temples but not one were found: Archaic Artemision and Classical Artemision.Classical Temple were erected on the foundations of the older one.

Pliny had stated that the Artemision (probably he meant the later temple) had 127 columns and 36 of them standing on sculptured drums which were decorated with carved reliefs. Pliny had also specified that these decorated columns (columnea caelate) were to be found in the front (west side) of the Temple. Fragments of columnae caelatae's were unearthed by Wood. One of them has been restored and can be seen in the British Museum. Although the archaic Artemision lied beneath the Hellenistic construction it has been possible to reconstruct it with some certainty. As

with the other two Artemisions of Asia Minor, Temple of Artemis at Sardis and Hermogenes' Temple of Artemis at Magnesia-on-Meander, the principal façade of the temple was towards West.The Hellenistic Temple was erected as a late classical structure over an archaic ground plan. It was the Ionian architect Paeonius together with Deinokrates (or Demetrios) who took up the task of completing the Classical temple.

5. THE TEMPLE OF APOLLO AT DIDYMA

Paeonius together with the native Daphnis were the architects of the Classical Temple of Apollo at Didyma. Like in the previous examples, the archaic temple was also burned. It was burned by Darius in 494 BC. Probably the construction of the Classical temple was started at about 313 B.C. , after Alexander the Great had regained independence for the Ionian Cities. Paeonius made the plans of the Didymaion to rival the Artemision. With this, Paeonius would be perfecting the work he had started at Ephesus. Having the same approximate dimensions, it possesses the characteristics of the previous temple of Artemis at Ephesus. It is the third hypaethral and dipteral temple. The number of ascertained points of resemblance between this temple and the previous ones is a consequence of the direct descent of information and experience from master to master and from temple to temple. The known differences seem to be the improvements on the older temple. Didymaion was designed as late classical structure, but it subsequently passed through all the stages of Hellenistic execution. This was the first and only decastyle structure among the great Ionic temples. Enough remains have survived from this temple to make its reconstruction quite certain . The temple was remarkable for its size—163 ft. (49.6m) in the front, and 366 ft (111.55 m) in the flanks. It stood upon a 3.4 m high platform with a flight of 7 steps.120 columns were disposed, each over 64 ft. (19.5m) height, the tallest in the Greek world. Naiskos was exposed to the sky. The cult statue of Apollo was returned by Seleukos I, the King of Syria about 300 B.C.

6. THE TEMPLE OF ARTEMIS AT SARDIS

The fourth of the great Ionic temples is the temple of Artemis at Sardis. It is the second of the greatest Ionic temples after Didymaion that has survived to day. Thanks to its well-preserved details its reconstruction can be made with reasonable certainty. Two of the columns are still standing with their capitals. One of the architrave blocks survived as a whole. Three more capitals were discovered during the excavations of Butler [9].

The two capitals furnished by the two standing columns are called by the letters A and B.The others are annotated by the letters C, D, E, F and G. The capital C was taken to the Metropolitan Museum of New York, while the others remained. With large volutes and egg-and- tongue on the echinus, they reflect the classical and even archaic traces of style. The temple had 8 columns at both ends, and 20 along the flanks. The stylobate is 45.51 m by 97.94 m. Although in its size and outer appearance it resembles the other three great dipterals, it differs from them in having no inner colonnades on the flanks.

7. APPLICATION OF THE 3D GRAPHICS TECHNOLOGY

The ultimate goal of this work has been, as its title implies, to present the reader the most faithful reconstruction of the four great temples of the Ionian world. The method for such a goal spans 3D graphics technology as well as archaeology. In order to make the archaeological information visible the cutting-edge 3D graphics technology is applied. Two of the most widely used methods have been as follows:

a) Detection of the vertices, segments and polygons and establishing the presence of connectable edges among the surviving fragments. This method is depicted below where the head of a statue is fixed by attachment of two broken parts (Fig. 1).

b) Completing the missing parts of a fragment by using the

canonical forms. This method is known as enhancement and was extensively employed in reconstruction of the parts like capitals and column bases.(Fig.2)

Fig.2 depicts the application of enhancement method in reconstruction of an Ionic capital. This type of an application calls for canonical models of ionic capitals for reconstruction. The spiral curves of the volutes do not lend themselves to known forms of mathematical expressions. Each spiral curve is different and like the fingerprint of the temple. How these curves were obtained for each of the Ionic temples will be covered in a follow-up article. For obtaining 3D effects the 3D models are projected from three different workstations as shown in Fig. 3.

8. RESULTS

The rendered images of the 3D- reconstruction of the four great Ionic Temples are given in Figs. 4-7. With the advent of computer graphics it has been possible to reconstruct them as if they are standing unharmed and in their original state. In showing vividly how ruined buildings once looked; Reconstruction work can be equally instructive in clarifying how such buildings could not have looked.

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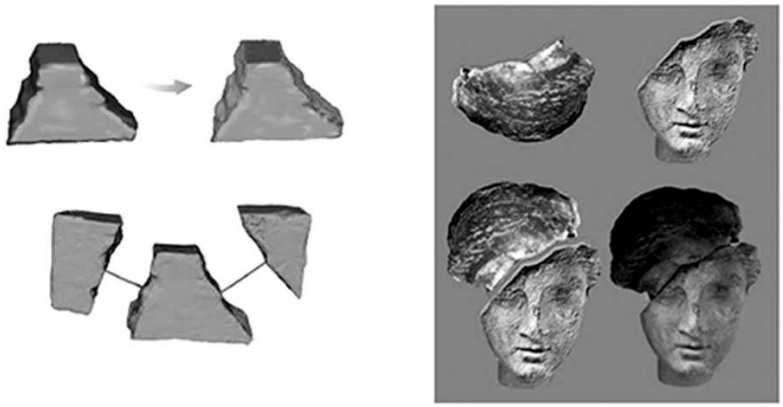

a) Detection of connectible edges

b) Fixing the broken head of a statue by attaching connectible edges

Figure 1. Reconstruction by detection and attachment of connectable edges.

Figure 2. Reconstruction of an Ionic capital by using enhancement.

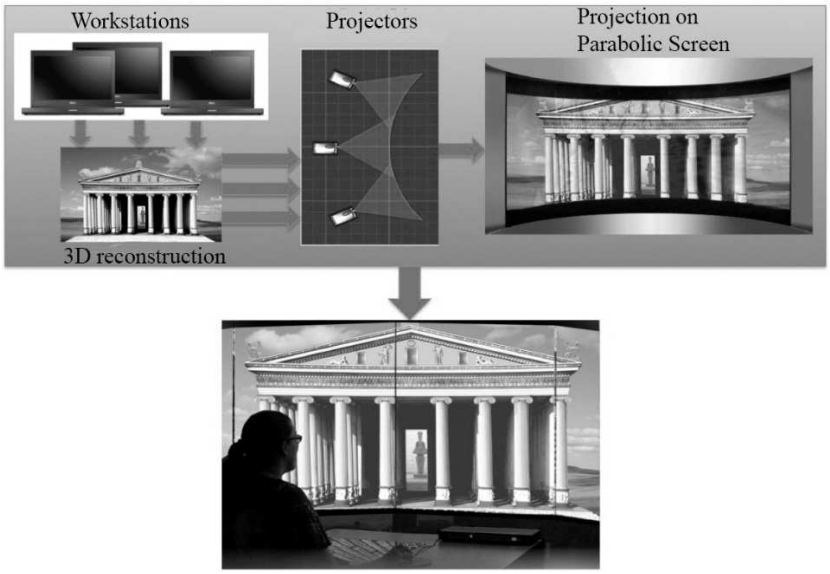

Figure 3. Projection of 3D model

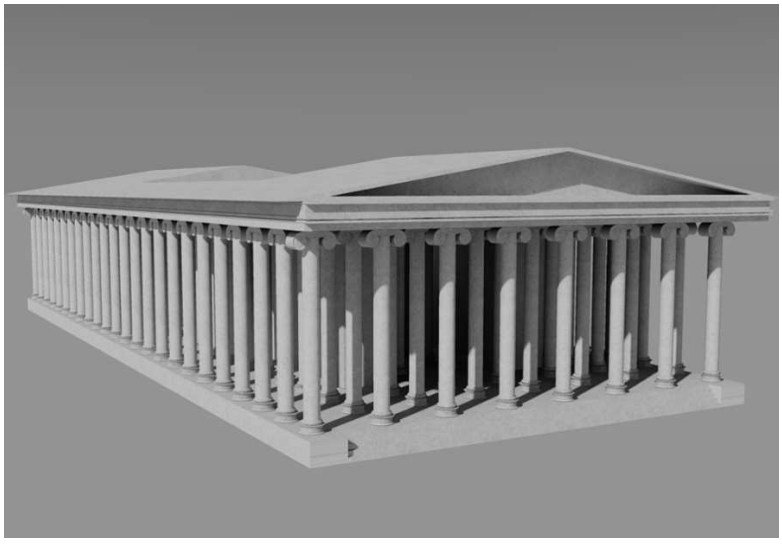

Figure 4. Reconstruction of Heraion (Polykrates) Temple

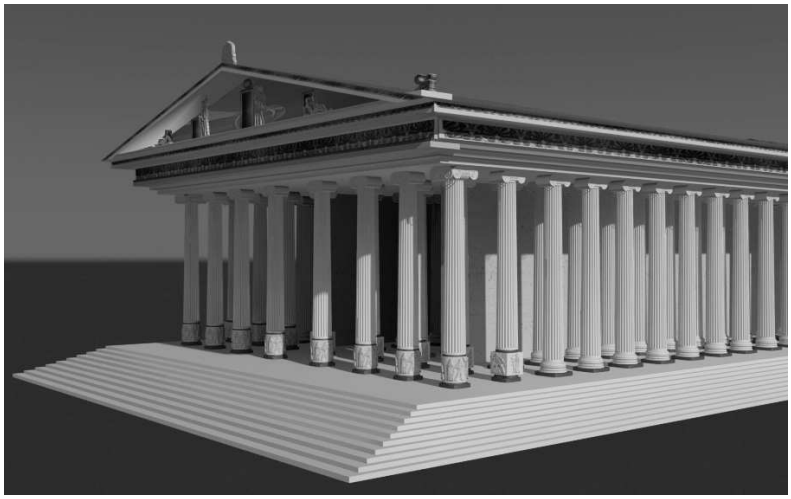

Figure 5. Reconstruction of Artemision (Classical Temple)

Figure 6. Reconstruction of Didymaion

Figure 7. Reconstruction of Temple of Artemis at Sardis