ITU A|Z • Vol 13 No 2 • July 2016 • 185-193

Augmented reality (AR) of historic environments: Representation of Parion Theater, Biga, Turkey

Derya GÜLEÇ ÖZER[1], Takehiko NAGAKURA[2], Nikolaos VLAVIANOS[3]
[1] dgulec@mit.edu • Department of Architecture, Faculty of Engineering And Architecture, Istanbul Kemerburgaz University, Istanbul, Turkey
[2] takehiko@mit.edu • Computation Group, Department of Architecture, Massachusetts Institute of Technology, Cambridge, United States
[3] nvlavianos@gmail.com • Department of Architecture, Massachusetts Institute of Technology, Cambridge, United States

Received: January 2016 • Final Acceptance: April 2016

Abstract

Similar to other fields in architecture, architectural representation involves adopting digital methods and digital data at a fast pace as in the case of cultural heritage preservation often referred to as digital heritage. Among these digital technologies, *augmented reality* (AR) techniques are well-known since they contribute a lot to the representation process. In addition to various sectoral uses, the use of AR tools and methods is important to study and research with regards to their integration in historical representation.

This study aims to represent historical heritage in terms of photogrammetry and AR methods for the Parion Theater, Biga, Turkey, dates back to 1st-2nd century A.D. and has been under excavation since 2005. There is a need for a high-tech visualization of cultural heritage because it is important to share and visualize data for such users as historians, archaeologists, architects, tourists and so on. The paper uses MULTIRAMA, a method previously developed by ARC Team (MIT) in 2013, which aims to represent the "unseen" to such users by documenting and visualising the site for use in this user-friendly app.

The method will support cultural heritage representation in the following stages: i) documentation (*use of photogrammetric methods),* ii) data process and modeling, (*correcting 3D photogrammetric images using AR)* and iii) presentation (*3D reconstruction of the cultural heritage via an AR application)*. This holistic and low cost approach will focus on the problem of accurate reconstruction and representation in cultural heritage of Parion.

doi: 10.5505/itujfa.2016.66376

Keywords
Augmented reality (AR), Digital cultural heritage, Documentation, Parion.

1.Introduction

Among other historical artifacts, architectural heritage is the most difficult to present in museums. A historical building piece is obviously too big to fit in an exhibition room. Even if it is done, since it is disconnected from its strong ties to the context and surrounding, it loses important data and visual appearances. Looking from another perspective, in a historic site, usually it is meaningless to look at the ruins without knowing how the ruins previously looked. Alternatively, architects commonly use photographs, videos, scaled drawings and physical models as a way of translating the original situation into useful representations. But again, these representations are only fragments of the buildings, and are in plan/ section/ elevation format using architectural language. For instance, relating a 3D architectural piece with its scaled drawings, such as its plans or sections, is quite hard and complicated for people who are not experts in this field or are unfamiliar with architectural language. Therefore, the spatial relationship between the real architecture and its presentations of various kinds forms the problem in this study.

Augmented Reality (AR) and Virtual Reality (VR) are two concepts that are widely used in terms of representation. Although usually referred to as being in the same category, augmented reality and virtual reality are two different concepts (Bound et al. 1999). Augmented reality is an environment with virtual objects added onto real world objects, and in virtual reality, the environment and the objects are all virtual with no actual objects present.

Focusing on AR use in cultural heritage, Paul Reilly (1990) was the first to mention virtual archaeology, referring to 3D computer models of historical artifacts. In recent literature, Lucet's work on virtual reconstruction of the archaeological sites was promising (Lucet, 1997), and was followed by dynamical interactive visualization techniques (Gillings, 1999; Lloret, 1999). Later, as an important book on digital heritage, "Virtual Archaeology" (Barcelo et al., 2000) was a key source for latest works that have been developed. Among the articles in this book, there were some important contributions on modeling and simulation in reconstruction (De Nicola et al., 2000; Goodrick, Harding, 2000; Pasztor et al., 2000; Pope, Chalmers, 2000) and virtual interactive environments (Frisher et al., 2000; Kadobayashi et al., 2000). There have also been recent studies on virtual interaction projects (Bonfigli et al., 2000) and virtual environments (Kirkley, 2005).

A general literature review shows that there have been studies carried out on historical structures and virtual reality applications. These studies are grouped as: i) the works running on tablets, which make it easy to perceive the models, ii) works creating different perceptions using a virtual reality interface in the physical environment, and iii) works presenting an interactive information representation. The method adopted to be used in this paper, Multirama, can be considered among this third group.

Before Multirama, there was some methods developed by T. Nagakura and ARC Group (MIT). The Space Barcoder installation (Nagakura, 1998), used in an exhibition of a building that has small barcode tags pinned on physical architectural model, in order to see a render or video recording of the live space. Digitarama (Nagakura, 1997), was a method placing 3D printed model of Hagia Sophia, visualizing the digital models and inner space with two digital screens attached on two arms. Later Deskrama was developed (Nagakura, Oishi, 2006) for synthetic visualization of unbuit modern architecture. These previous works were the progress in developing a new method called Multirama.

Multirama (previously called Ramalytique) was a method developed by ARC (Architecture Representation Computation) Group in MIT in 2013, with collaboration of Takehiko Nagakura, Woong-ki Sung, Daniel Tsai and Howard Burns. It was an interactive AR interface to represent artifacts or buildings. Later, in 2015, a new collaboration was made by authors, to carry out a research on archaeological sites using Multirama.

Dating back to 1st-2nd century A.D., Parion /Biga is among the very valuable archaeological sites in Turkey, being relatively a new discovery which has been under excavation since 2005. Among its architectural structures throughout the city, Parion Theather (1st-2nd century A.D.) is an important one since it is situated on the center of the city with the advantage of slope. Parion Theater was built just as the other theatres in Anatolia leaning on the slope, unlike the Side Theatre. Thinking of its topographical features, it was located on the most appropriate part of the city. In the theatre, a very limited part was revealed by the excavations in the scene building, in the scaenae frons section (the decorated background of the stage) and in the area likely to be the orchestra. Owing to the data having been acquired during the excavations so far, it has been understood that the original structure has been destroyed for several times. The biggest destruction happened to the wall in front of the scene building. On the structure, the extensions and repairs from different periods could be seen but certain dating is not possible with the current finds (Basaran, 2013).

In the light of this information, it is understood that the ancient city, Parion, is worth preserving and it has a quite important architecture, besides, a great support for its representation and reconstruction is needed with the ongoing. The fact that excavations in the city has been carried out for more than 10 years, the architecture has revealed recently, and the documentation studies were put forward in the previous excavation seasons. So as to be able to start the architectural preservation and reconstruction studies with their architectural representations in the upcoming years, documentation and modeling studies are needed. With the work of this paper, the need in this field is fulfilled, furthermore, the augmented reality interface, Multirama, is used for the representation of the ancient architecture. This paper utilizes the use of Multirama; to document, calculate, and present the architectural cultural heritage of the ancient heritage, Parion Theater, which is one of the most important historical theaters in Anatolia. This study makes a significant contribution to the digital cultural heritage literature in many aspects.

This work has been carried out in three stages: i) documentation, ii) data process and modeling, and iii) presentation. During the documentation stage, we enable the use of photogrammetric methods. In the processing and modeling stage, we provide tools for correcting 3D photogrammetric images using AR application with UNITY software. In the final stage, the resulting accurate 3D reconstruction of the cultural heritage site is presented to the audience with a viewer AR application. In Multirama, the models are united with other drawings or 3D models in the augmented reality interface through the use of tablets to look at physical architecture models. Indoor use of this method, such as in museums and exhibition halls, is predicted. The significance of this study is to introduce a holistic and low cost approach focusing on the problem of accurate reconstruction and representation on cultural heritage of Parion Theater.

The outcome of the research and the benefit to the related fields are summarized below:

- Use of a low-cost, holistic method utilizing AR technologies to represent digital heritage,
- Integrity of architectural drawings, such as sections, plans, elevations in 3D context,
- Easier perception of the environment with 3D models compared to 2D drawings, for the work of archaeologists, historians, restorators,
- Revival of the context connection that is lost due to natural conditions, via a user friendly app.; easily usable, understandable and informative medium running on a tablet or smart phones for children and students interested in archaeology.
- Easier perception for tourists who can be informed about the heritage architecture and can have an idea of the original site while visiting the archaeological site,
- Contributions to the presentation and promotion of Turkey's cultural heritage and the preservation of ancient ruins through 3D documentation.

2. Method

Multirama (previously named as Ramalytique) was first developed in 2013 by ARC Group of MIT; Takehiko Nagakura, Woong-ki Sung, Daniel Tsai and Howard Burns. This first work was an AR-based prototype with marker-based sensing method on a common handheld device, visualizing digital contents of a Renaissance villa by Palladio. In 2015; authors have collaborated in order to use this previously developed method on an archaeological site, Parion Theater. The study has been carried out in six months period, technical works took place in MIT and site works in Parion, simultaneously.

Multirama method combines photogrammetric digital model and the solid modeling geometry either in the form of simply digital models or the co-existent of digital and 3D-printed models. In this method, the result of photogrammetry model is 3D printed and combined through augmented reality with the broader context of the site (photogrammetry) and speculative design of former state of the site (solid modeling geometry). A viewer looks at a scale model through the camera of a tablet computer and can interactively turn on and off various representations overlaid on the live video feed of the model. (Nagakura, Sung, 2014; Nagakura et. al. 2015)

Addition to previous work by ARC group, a collaboration was built in order to use Multirama in an archaeological setting, which is subject to this paper. Parion is an important ancient city situated in Biga, Turkey; dating back to 600 B.C. The excavations have started in 2005, since then, major architectural findings are found such as roman theather, bath, odeion, terraced structures and thermal plant archaeopark fields. Among these, Parion Theather (1st-2nd century A.D.) is an distinct discovery since it is one of the most important ancient theathers in Anatolia.

Among this paper, the Multirama method is used in order to represent Parion theather in means of Augmented Reality (AR). During the research between June-November 2015, the site work was conducted by Omer Ozturk and Mustafa Yildizli in Parion, whereas the technical work was done by authors in MIT.

The entire project requires different stages of capturing the original site, processing the information and producing the output in the form of an artifact of physical and augmented reality models. By using drones with cameras as well as handheld cameras, it can be possible to capture the entire site through photogrammetry and create a data set of pictures. The logic is that every single picture needs to have a significant part that overlaps with the adjacent one. The difficulty of this step is related to the precision of the angle of drone given the fixed position of the camera.

By stitching the pictures, a 3D digital model is created that has texture mapping according to the original site. The resolution of the pictures (input) and the meticulous overlapping parts between the pictures desire higher resolution and precision not only on the texture mapping, but also on the 3D geometry. The manipulation of this digital model allows to have a simulation of the original site even if the resolution of the digital model is decided to be decreased in the process.

The next stage is to use the photogrammetry model in order to design a solid modeling geometry. By using a fixed measure of the original site, we adjust the photogrammetry model to the appropriate scale. The precision of this geometry gives the exact dimensions and proportions of the entire site. So, it is possible to measure other parts of the site without the need to return back to the original site. This means that the photogrammetry model helps us to design directly clean geometry – solid modeling.

The method is conducted in three phases: i) documentation, ii) data process and modeling, and iii) presentation.

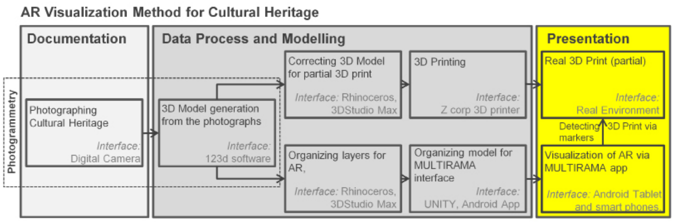

Figure 1. *AR visualization method with MULTIRAMA (Credit: D.G. Ozer, T. Nagakura).*

The method is detailed in the following sections and is shown in Figure 1.

2.1. Documentation

In this first phase, it is important to document the Parion Theater via photographs before moving on to the 3D modeling phase. Since the aim is to create a 3D model out of photographs using 123d Catch software, there are important issues to keep in mind.

2.1.1. Key issues while photographing the site

Depending on previous experiences on capturing a real environment, there are some key issues to keep in mind, in order to avoid undesirable results caused by technical difficulties or natural conditions.

Firstly, Autodesk 123d Catch software is used to model the three dimensional object from the photographs. This software is free, but it allows uploading a maximum of 70 photos at a time. There is no need for a professional camera to take the pictures; a normal digital camera or even a smart phone will work, but the photographs must be at least 3 –4 MP resolution.

Secondly, when photographing an object, one should capture the object from every side, for example, at least 20 photographs are needed for a single column. When capturing, it does not work if you stay in the same spot and shoot at different angles. You have to move the camera slightly (Figure 2).

Thirdly, one needs to be careful with shadows and shades. If the sun is high and the object has shade on it, the exposures of the lightened and darkened parts will be different. This situation is not suitable for photogrammetry. You either have to use manual exposition and keep it the same at every angle, or you have to capture the object on a cloudy day. Photographing early in the mornings produces better results.

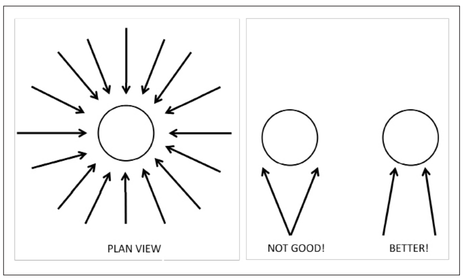

Figure 2. *Left: How to capture a column, Right: Results are better when capturing from different angles (Credit: D.G.Ozer, T. Nagakura).*

It is important that the photos overlap each other. The overlap should be a third of the next photo. Also it is better to capture an object from a certain distance. If another object is interfering with the shot, you can capture the image from a different angle. Additional issues to keep in mind while uploading capture photos to 123d Catch:

- One should shoot at least one picture for every 10 degrees. For example, you need at least 36 pictures for a small building.
- In order to help the software identify the same surfaces, placing an image (picture) on the surface will help.
- If the capture is a repetitive structure, the software may get confused. In order to prevent that the surrounding features can be included, so that the pictures are different from each other.
- In repetitive structures, in order to prevent confusion in the software, 90 degrees of capture can be processed at one time (30 pictures). Later, the rest can be processed, each time using a 90-degree angle.

2.1.2. Fieldwork

The ancient city, Parion and its architectural value is the first issue to be focused on during the literature review. In 2005, archaeological excavations started in the ancient city, Parion, locating on the northwest of the Troas Territory (Biga, Turkey). Since then, excavations have been continuing in the south necropolis within the seven areas of theatre, roman baths, terraced structures, odeion and thermal plant archaeopark fields (Basaran, 2013).

Parion has a natural harbor and situated between the two shores of a river, which lies on the sea like a tongue. With these topographic features, via being close to the two bosphoruses and having the natural harbors, Parion has got a highly important geopolitical position (Basaran, 2013).

Situated at the center of the city, with the advantage of a slope, the Parion Theather was built just as other the-

Figure 3. *Parion aerial view (Credit: Parion Archive).*

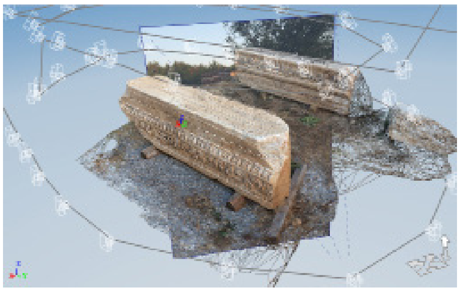

Figure 4. *3D model of the architraves using 123D Catch software (Credit: Omer Ozturk).*

atres in Anatolia, leaning on a sloped ground, in contrast to the Side Theatre. Thinking of its topographical features, it was located on the most appropriate part of the city (Figure 3).

Excavation of the structure began in 2006, and a very limited part was revealed by the excavations in the scene building, in the scaenae frons section (the decorated background of the stage) and in the area likely to have been the orchestra. It is possible to date the architectural pieces, which constitute the majority of the finds and look similar to each other, in addition to the patterns and the reliefs, to the second half of the 2nd century AC (Basaran, 2013).

Therefore, only the scene building was documented, but the final AR represent the whole structure.

By the beginning of the excavation season, the photogrammetric surveys started in the Parion Theater, with a small architectural piece (an architrave). The architrave was successfully digitalized with almost 30 photographs, 360° around (Figure 4).

With the help of this preliminary work, experience is gained on photo shooting angles, the necessary photo count for 3D modeling and the best time of the day in terms of sun position. After being successful in this small work, larger architectural pieces is captured, with a camera on a standing position.

In the first attempts, some difficulties are faced in photo shooting. The closeness of the architectural elements (walls) and having different measures were two major problems. The other problem was elements could not be captured at the right angle from a standing position. In order correct the northern side that could not be 3d modeled, manual stitching command is used in Autodesk 123d Catch. With the help of this command, the aimed points could be manually set on the photos, reconstructing the 3D model. After gaining shooting experience, the theater is captured piece-by-piece.

After having problems with photographing from the standing position, it is decided to shoot from high above. Zeppelin is used first, but it did not work after all. The main reasons were the bad weather conditions, the inconstant move of Zeppelin and the sun position (Figure 5).

After the unsuccessful work with the Zeppelin, the crane is decided to be used (Figure 6). Using the crane was successful, and among the good shots, 70 of the pictures were chosen to up-

Figure 5. *Alternative techniques to capture the site via photogrammetry (Credit: Parion Archive), Left: Use of zeppelin, Right: Use of drone (Credit: D.G. Ozer).*

Figure 6. *The use of crane to capture the site (Credit: D.G. Ozer).*

Figure 7. Left: On site photograph (credit- Parion Archive) Right: 3D model from photogrammetry in 123D software (Credit: Omer Ozturk).

load on 123d. From this, the best result was achieved (Figure 7).

2.2. Data process and modeling

Once the photographs are taken, they are uploaded to 123d Catch software to construct the photogrammetric 3d model using software's .3dp format. When the results are satisfactory, they can then be opened using Rhinoceros software. In our case, when the file was opened, it had seven polygon meshes, which were very dense and hard to work with. The polygon count is decided to be reduced using 3d Max.

Since the resulting model had a reduced polygon count in Rhino, the closure of the object have to be checked. The best thing to do was reduce the non-manifold edges to zero and the naked edges to a minimum count and later, to erase the naked edge parts with "deletemeshfaces" and apply "fillmeshhole" again. In this way, the desired result can be reached (Figure 8).

After the file is ready for .STL format, it is important to reduce the file size. Holes have to be made in the model to reduce the file size.

The final outcome was somewhat fragile, so it should be hardened with ZAP CA super glue. This glue is very poisonous and gloves and masks need to be worn while spraying the glue. Also, the glue is very harmful to smell, so the air conditioner should be on during the whole process. The outcome is white and rigid. In the final step, to make the AR, scene target is needed as a marker. The AR software will read the marker for the visualization, and show the desired image.

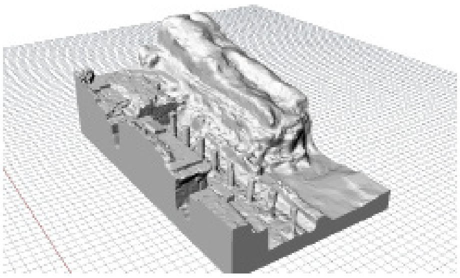

Figure 8. Cleaned up mesh in Rhino: Ready for .STL format (Credit: D.G. Ozer).

Next, parion_AR_v1.apk file is installed, which was generated by the team and is reorganized for this project using UNITY software into an Android device. The file was copied onto the device and the file manager app was used to launch the apk file. This installed the Unity AR app.

2.3. Presentation

Finally, all necessary visual elements to be presented such as AR models, sections and plans were prepared in Rhino and processed in UNITY. The necessary data were implemented in MULTIRAMA's interface using Android applications.

Working on the AR model:

- The 3D model was corrected in Rhino, and the layers were organized as it would be seen in an exhibition.
- It was important to be careful while converting the file between Rhino and 3D Max. While reducing the vertex count in 3D Max (Pro-optimizer), material info needs to be turned on in the Pro-optimizer dialog box or the model will lose its texture data.

While viewing in an exhibition, you hold your smart device looking at the physical object. The app reads and detects the marker, and show you the desired format. In this case there are four options; such as site model, section aa, section bb and above structure (Figure 9). You can move the device around the physical object (part of theater in this case), and your AR will turn accordingly.

3. Results

The AR is presented in an exhibition and on the web site (www.deryagulecozer.com). The widespread effect will be increased with the academicians, students and specialists' use of this project's results in the related sectors of Digital Cultural Heritage.

While there is vast literature on building documentation methods in cultural heritage, existing methods are disconnected and are often extremely costly, such as laser scanning. This study is important since it could lead to the development of a low-cost, holistic method utilizing AR technologies to represent digital heritage.

The project's results will have a widespread effect in two ways. First, the results will directly contribute to the archaeological work (Parion, Biga) of visualization/representation and restoration/restitution. In this related work, re(presentation)/preservation/restoration of cultural heritage studies will gain speed. Second, deployment of VR/AR technology use in digital heritage, with the introduction of this method to academia will ensure the continuity of postdoctoral studies and collaboration.

This paper contributed to the digital cultural heritage literature among several topics, such as:

- Archaeological and Architectural Representation: With the help of the developed virtual technology interface, Multirama, it is aimed to contribute to academic studies of archaeologists, historians, restorators etc. in order to make better analyses of and interpretations of archaeological findings.
- Reconstruction and Restoration: With the help of the developed virtual technology interface, Multirama, it will be possible to model and unite separate parts, have a better understanding and reconstruction of the original structure. For the future work, it is planned to use this method and develop it for further studies such as restructuring the stones of Parion Theater for rebuilt.
- Advertising and Presentation of the Turkish Archaeological Sites (Touristic Purposes): The easy use of the developed interface aims to be used for the touristic purposes, and presenting the national history as well. Ministry of Culture and Tourism onwards, the project is aimed to enable similar projects, and be applied widely in similar sites.

Figure 9. *Final enstallation and AR (Credit: D.G. Ozer, T. Nagakura).*

Acknowledgement

This study was made during post doctoral research in ARC Group (MIT), with collaboration of authors in 2015. We would like to thank Omer Ozturk and Mustafa Yildizli for their contributions in the field work. We also would like to thank the rest of ARC Group (MIT) previously collaborated in Multirama project; Woong-ki Sung, Daniel Tsai and Howard Burns. The project presented in this paper was funded by the post doctoral research grant of TUBITAK 2219 fellowship and Istanbul Kemerburgaz University.

I would like to give my sincere gratitudes to Parion Archaeological Expedition Team, Prof. Dr. Vedat Keles and Asst. Prof. Dr. Ertug Erturer for providing the study environment and for their invaluable support.

For detailed information please refer to web site, www.deryagulecozer.com.

References

Barcelo, J.A., Forte, M., Sanders, D.H. (2000) "The Diversity of Archaeological Virtual Worlds", *Virtual Reality in Archaeology*, eds. By J.A. Barcelo, M. Forte, D.H. Sanders ArcheoPress, Oxford.

Basaran, C. (ed.) (2013) "Antik Troas'ın Parlayan Kenti: Parion", Ege Yayınları, İstanbul.

Bonfigli, M.E., Calori, L., Guidazzoli, A. (2000) "*Nu.M.E.: a WWW Virtu-*

al Historic Museum of the City of Bologna",SAC Proceedings, March 19-21, Como, Italy.

Bound, A.C., Haniff, D.J., Baber, C., Steiner, S.J. (1999) "*Virtual Reality and Augmented Reality as a Training Tool for Assembly Tasks*", Proceedings of 1999 IEEE International Conference on Information Visualization, pp. 73-80.

De Nicola, R., Giordano, A., Guarino, S., (2000) "Ray-Tracing Techniques In A Parallel Environment: The Case Study Of A Horse Grave", *Virtual Reality in Archaeology*, eds. By J.A. Barcelo, M. Forte, D.H. Sanders ArcheoPress, Oxford.

Frischer, B., Abernathy, D., Favro, D., Liverani, P., De Blaauw, S., (2000), "Virtual Reality and Ancient Rome: The UCLA Cultural VR Lab's Santa Maria Maggiore Project", *Virtual Reality in Archaeology*, eds. By J.A. Barcelo, M. Forte, D.H. Sanders ArcheoPress, Oxford.

Gillings, M. (1999) "Engaging Place: a Framework for the Integration and Realisation of Virtual-Reality Approaches in Archaeology." *In Archaeology in the age of the Internet. CAA,* Edited by L. Dingwall, S. Exon, V. Gaffney, S. Laflin, M. Van Leusen. Oxford: British Archaeological Reports (Int. Series, S750).

Goodrick, G., Harding, J. (2000) "Virtual Reality at the Neolithic Monument Complex of Thornborough, North Yorkshire ", *Virtual Reality in Archaeology*, eds. By J.A. Barcelo, M. Forte, D.H. Sanders ArcheoPress, Oxford.

Kadobayashi, R., Nihimoto, K., Mase, K. (2000) "Immersive Walk-Through Experience of Japanese Ancient Villages with the Vista-Walk System", *Virtual Reality in Archaeology*, eds. By J.A. Barcelo, M. Forte, D.H. Sanders ArcheoPress, Oxford.

Kirkley S. J. (2005). "Creating Next Generation Blended Learning Environments Using Mixed Reality", *Video Games and Simulation*, TechTrends, 49(3), pp. 42-89.

Lloret, T. (1999) "Arqueología Virtual y audiovisual. Una nueva propuesta en la difusión del conocimiento arqueológico." *Revista de Arqueología XX*, 213, pp. 13-19.

Lucet, G. (1997) "The virtual restitution of the mesoamerican site of Cacaxtla: a methodological point of view", *Archeologia e Calcolatori*, Roma, 8, pp.129-138.

Nagakura, T. (1998) Gushikawa Orchid Center. 17th Exhibitgion of Winning Architectural Models and Drawing. SD Review, December 1998, pp.36-38.

Nagakura, T. (1997) "Digitarama", Ken Sakamura and Hiroyuki Suzuki, eds. *The Virtual Architecture*. Tokyo: Tokyo University Digital Museum.

Nagakura, T. and Oishi, J. (2006) "Deskrama". Proceedings of ACM SIGGRAPH 1998, Emerging technologies. Article No. 6. New York: ACM New York.

Nagakura, T., Sung, W. (2014) "*Ramalytique: Augmented Reality in Architectural Exhibitions*", Conference on Cultural Heritage and New Technologies 19th Prooceedings, 3-5 Nov., Vienna.

Nagakura, T., Sung, W., (2016) "*RAMALYTIQUE (a.k.a. Multirama AR) A Tablet to See the Lost in Translation*" link: http://cat2.mit.edu/multirama/

Nagakura, T., Tsai, D., Choi, J. (2015) "*Capturing History Bit by Bit*", eCAADe 33th Prooceedings, 16-18 Sept., Vienna.

Pasztor, E., Juhasz, A., Dombi, M., Roslund, C. (2000) "Computer Simulation in Stonehenge", *Virtual Reality in Archaeology*, eds. By J.A. Barcelo, M. Forte, D.H. Sanders ArcheoPress, Oxford.

Reilly, P., (1990), "Towards a virtual archaeology", *Computer Applications in Archaeology* , Edited by K. Lockyear and S. Rahtz. oxford: British Archaeological reports (Int. Series 565), pp. 133-139.

Pope, J., Chalmers, A. (2000) "Pre-rendering acoustics and illumination for archaeological reconstructions Computer simulation of Stonehenge", *Virtual Reality in Archaeology*, eds. By J.A. Barcelo, M. Forte, D.H. Sanders ArcheoPress, Oxford.