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3D VISIBILITY ANALYSIS AS A MEAN TO VALIDATE ANCIENT THEATRE'S RECONSTRUCTIONS

ANÁLISIS DE VISIBILIDAD EN 3D PARA VALIDAR LAS RECONSTRUCCIONES DE LOS TEATROS ANTIGUOS

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Abstract:

Correct interpretation of lost monuments is something really craved from an archaeological point of view but most of the time it is also very hard to obtain. In recent years, Virtual Archaeology and 3D modelling are providing valid instruments to facilitate the comprehension of ancient scenarios, and new input to investigate different aspects of the past. A new methodology is presented in this paper in order to achieve a high reliability of reconstruction of architectural elements of the large Roman theatre of Gortyn in Crete, through 3D visibility analysis.

Key words: 3D visibility analysis, 3D modelling, virtual archaeology, Roman theatre, Gortyn, Crete.

Resumen:

La correcta interpretación de los monumentos perdidos es algo realmente anhelado desde un punto de vista arqueológico, pero difícil de obtener en la mayoría de los casos. Desde hace unos años la Arqueología Virtual y el modelado 3D se consideran instrumentos válidos para facilitar la comprensión de los escenarios antiguos, permitiendo investigar aspectos diferentes del pasado. En este artículo se presenta una nueva metodología para conseguir una elevada fiabilidad en la reconstrucción de los elementos arquitectónicos del gran teatro Romano de Gortina, en Creta, por medio del análisis de la visibilidad en 3D.

Palabras clave: análisis de visibilidad en 3D, modelado 3D, Arqueología virtual, teatro Romano, Gortina, Creta.

1. Introduction

During the centuries, the discipline of archaeology has developed theories, methods and instruments whose first aim is to understand and reconstruct the past. In more recent time, Virtual Archaeology gives the possibility to visualize and interact with the past, but above all it can be useful to verify hipothesis and reconstructions if used together with well established methodology such as archaeological reports, written sources, plans and pictures, plus geophysical prospection and 3D modelling.

GIS is widely used in archaeology since many years, above all to study ancient landscapes. Now, with the introduction of 3D spatial analysis tools (e.g. 3D analyst toolkit in ArcGis), is also possible to analyze 3D archaeological environments. In this study, visibility analysis has been done for five 3D models, representing different hypothesis about the architectural reconstruction of the large Roman theatre of Gortyn, in order to know which is the most realistic one, verifying the visibility of the stage from observer points placed in the cavea. The 3D model with the best visibility according to the analysis will be further verified by virtual acoustics.

2. Methodology and preliminary results

The large theatre placed on the south-east slopes of the acropolis of Gortyn was modelled through the software 3D Studio Max 2013 and several reconstructions have been made taking into account different characteristics:

1. The first 3D model, taken as reference reconstruction for the rest, is the result of the integration and interpretation of three different plans (one by Belli, end of XVI century, one by Falkener (1854), midst of XIX century, and one by Taramelli, beginning of XX century), the section of Taramelli (1902), geophysical prospection (Sarris and Papadopoulos 2009), orthophoto, Vitruvian rules (Pollione 29-23 a.C.), descriptions of travellers and scholars (Manzetti *et. al.* 2015).

2. In the second model the stage has been placed closer to the cavea because in the first model it is in an unusual position, indicated by Belli (Beschi 1999), namely too far from the seating area.

3. For the third model, the first one has been used modifying the wall of the diazoma and making it 1,40 m

higher. This wall is often higher than the one indicated by Taramelli, because in many ancient theatres arcade are opened in that wall to allow the entrance of the spectators and actually these possible arcades are testified by Barresi (2004). The difference height of this wall is also evident in a picture within the paper about the current excavations of the theatre, but it does not record any measure and it does not show any arcade (Kanta *et.al.* in press).

4. Another model was constructed as a combination between the second and the third, therefore with the stage and the diazoma's wall modified.

All these 3D models have been exported as .3DS files in order to easily import them in ArcScene as a multipatch shapefile (this application has been preferred to use 3D analyst tools of ArcGIS because it allows 3D visualization).

A grid indicating the observer's locations, at some of the spectators' seats, has been realized in AutoCad 2013 and then add to ArcScene catalog and export to shapefile. The grid consists of six rows of points, for a total of 133 observers, each one of them placed 0,75 m up the corresponding seat, that it is the height of the eyelevel of a seated man. It has been decided to experiment with only six rows of points, located in the most interesting areas of the theatre, because the process for the visibility analysis in ArcGIS is long time consuming and six rows are enough to verify the quality of visibility, considering that from the large part of the central area of the theatre, the stage is obviously visible. In particular, it is important to examine the visibility conditions of the spectators seating at the sides of the building, whereas other rows are placed also in the central area to compare the results among different seats. The following step was to edit a line, approximately at the centre of the stage that covers almost the full length of the stage, placed at 1,60 m from the floor of the stage; this line represents the possible positions of different actors playing a performance, so it is the object observed by the grid's points. Subsequently, sight lines among the observers' locations and the line on the stage have been constructed through the "visibility" kit of 3D Analyst tool in ArcScene. This step is necessary in order to build the lines of sight (Fig. 1), that show through two different colours which spectators have a full visibility of the actors (green lines) and which have a partial visibility of it (red lines). In addition, the obstruction points have been also constructed: they mark which are the exact points which impede the complete visibility. In case of virtual architectural reconstructions based on uncertain data, this option is very useful because it gives the possibility to easily find the potential errors and modify the structure accordingly. In this specific case of study, obstruction points are, as expected, on the converging walls of the analemmata which cannot be made lower because they have to respect some safety measurements for spectators. Instead, the distance of the stage from the cavea has been easily modified to verify how it is possible to obtain a proper visibility.

This first procedure has been realized in order to have a 3D visualization of the line of sight: it allows to comprehend from which area of the theatre there is a total visibility and from which part there is a partial visibility, in order to decide which modifications could be necessary in the architectural structure of the building.

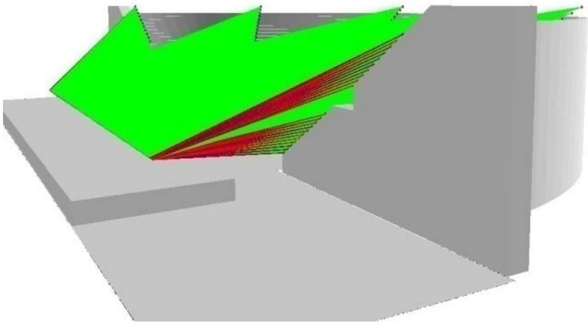

Figure 1: example of lines of sight of the model number 1, produced by 3D visibility analysis.

The second procedure that was employed in this research indicates the frequency of visibility of the theatre from the observers' locations and the result of the process is a raster with different colours representing the more and the less visible area. After having imported the .3DS file as a multipatch in ArcScene, a raster can be produced from it and used it, together with the grid, to process the visibility analysis. In this case, it is necessary to set the Z offset of the grid with respect to the raster, that is 0,75 m. This procedure produces a better output showing if the stage is actually visible from the large part of the spectators (in this case we are talking about the surface of the stage, we are not referring to the line representing the actors on the stage). In all the cases there is a high visibility of the stage from the selected seats, but it is clear that when the stage is farer (as indicated in Belli's plan) and the wall of the diazoma higher (as sustained by Barresi and by recent excavations), the full visibility (blue colour) expands at an even larger part of the stage. Figure 2 shows that the purple-fuchsia colour, indicating a partial level of visibility for a range of 103-118 spectators, occupies a very small area (the upper corners of the stage), while the blue colour (referring to the full number of spectators) is spread almost all over the stage.

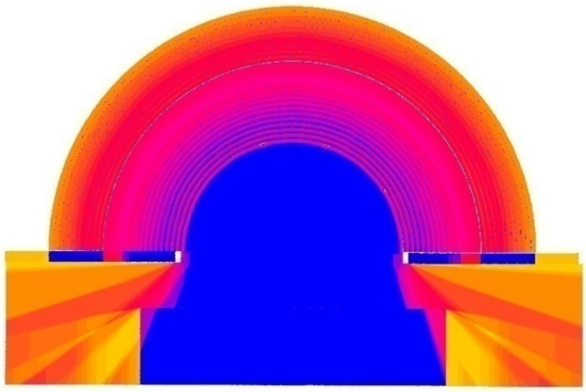

Figure 2: 3D visibility analysis' result of model n.3. The scale of colours indicates different frequency of visibility of the area of the theatre by selected seats in the cavea: light yellow means not visible by anyone, blue means visible from everyone.

Having established that the reconstruction with the stage far from the cavea and with the wall of the diazoma 2 m high (n. 3) can be the most correct one according to 3D visibility analysis, another test has been done using this reconstruction but with a higher stage. The first stage has been modelled with a height of 1,30 m because of the indications of Vitruvio about the architecture of the Roman theatres, and because that height looks coherent with the rest of the structure. But if we consider the other Roman theatres with converging analemmata (as in Gortyn's theatre) in Greece and Asia Minor, they have a much higher stage, from 2,13 to 3,55 m (Aphrodisia, Tralles, Ephesus, Miletus, Sagalassus). Then a stage of 2,75 m (average of the heights of the above-mentioned theatres) was add to this reconstruction (in place of the first one), and a new 3D visibility analysis has been processed, and its result indicates that the whole area of the stage is visible only from a range of 112-118 spectators and consequently not visible at all by 21-26 spectators.

Finally, the 3D model realized in the previous work has been modified accordingly to the new results, making the wall of the diazoma 2 m high instead of 0,60 m as indicated in Taramelli's section.

3. Conclusion and future works

This paper has highlighted the importance of the accuracy in projects of Virtual Archaeology and has suggested the use of 3D visibility analysis as an additional approach to accomplish such a goal especially when we are dealing with historical architectural reconstructions. The 3D visualization gives the possibility to observe our hypothesis and have a shape which is approaching a more realistic representation. The observation of a 3D graphical depiction of our idea helps to visualize problems and inconsistencies of the reconstructions. Therefore it is necessary and fundamental studing and analyzing architectural reconstructions in a fully 3D environments. The introduction of 3D visibility analysis enhances such kind of studies making possible the identification of potential obstacles in the visualscape and then understanding what is incoherent and misfitting in the reconstruction.

The results of this research show how 3D visibility analysis can easily and quickly sustain an interpretation and how significantly can support substantial modifications to a model.

The large Roman theatre of Gortyn has been taken as the pilot object of this study, but this is a method that can be applicable to all the ancient theatres and more generally to the ancient buildings reserved to public performances, such as odeons, amphitheatres, stadiums and circuses.

The next goal will be obtaining an additional validation or further information about the architectural structure of this theatre through the acoustics analysis of its 3D model.

Furthermore, if the acoustic analysis will confirm the position of the stage so far from the cavea, new archaeological questions will be formulated. Only two Roman theatres can be assimilated to the large one of Gortyn concerning the peculiar location of the stage: the one of Pola (Croatia) and the other of Bovillae (Italy), (Sear 2006). Both of them are localized on natural slopes and both are half digged in the rock and half built on substructures, exactly like the theatre object of this study.

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References

BARRESI, P., 2005. Gortyna: la sistemazione del teatro all'Acropoli in età Severiana. In: M. LIVIADOTTI and I. SIMIAKAKI eds., *Creta Romana e proto-bizantina, Atti del Congresso internazionale* (Herakleion, 23-30 September 2000). Padova: Bottega d'Erasmo, pp. 557-572.

BESCHI, L., 1999. *Onorio Belli a Creta: un manoscritto inedito della scuola archeologica italiana di Atene (1587*). Atene: Scuola Archeologica Italiana di Atene 95 pages.

FALKENER, E., 1854. A description of some important theatres and other remains in Crete, from a ms. History of Candia by Onorio Belli in 1856. *Supplement to the Museum of Classical Antiquities*. London: Trübner & Co. 63 pages.

KANTA, A., LIRINTZIS, A. and NIKOLOPOULOU, K., 2013. To megalo theatro tis Gortina: ta prota apotelesmata. In: *Proceedings of the I International Gortyna* Conference 2012, Gortyn, Greece, pp. 91-99.

MANZETTI, M.C., PARTHENIOS, P. and SARRIS, A., 2015. Integrating traditional methods with new technologies. Architectural study of the large theatre at Gortyn. In: *Proceedings of the Conference on Digital Heritage, International Congress* 2015*,* Granada, Spain*,* **2**, pp. 173-176. DOI: 10.1109/DigitalHeritage.2015.7419480.

POLLIONE, M.V., 29-23 a.C. *De Architectura*, book 5. Translated by MORRIS H.M., 1914: *Vitruvius the ten books on architecture*. London: Humphrey Milford 321 pages. Available: http://www.simeac.net/publications/vitruv-architecture/#Page_137

SARRIS, A. and PAPADOPOULOS, N., 2009. *Techniki ekthesi tis geofisikis ereunas & chartografisis tou chorou tou archaiou theatrou tis Gortinas.* Herakleion.

SEAR, F., 2006. Roman theatres. An architectural study. New York: Oxford University Press 465 pages.

TARAMELLI, A., 1902. Cretan expedition: XXI Gortyna. *American Journal of Archaeology*, 6, 2, pp. 101-165. Boston: Archaeological Institute of America.