Integrating spatial analysis and 3D approaches to the study of visual space: Late Bronze Age Akrotiri

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ABSTRACT

This paper[1] discusses the need for enriched approaches to visual space that combine the benefits of spatial analysis and VR applications. A prerequisite for the successful implementation of these approaches is the development of methods of analysis that take fuller account of the three-dimensional nature of the built environment, and the nature of human engagement with that space. Using a simple example from the built environment of Late Bronze Age Akrotiri as a case study, a method of analysis that integrates the functionality of GIS and 3D rendering software is presented. In the end alternative methodologies that move towards the management and analysis of real 3-dimensional data structures are proposed.

1. INTRODUCTION

The developments in 3D modelling and spatial technologies in the last fifteen years have provided archaeological research with a variety of tools for the description and analysis of the spatial entities that structure human visual space. However, it is notable that these technological trends have been looking into aspects of human visual experience in quite different ways. 3D modelling techniques, such as desktop Virtual Reality, investigate issues of visual perception through the interaction with 3D digital reconstructions that take into account the physical properties of real world features and environments, aiming to facilitate the formation of subjective, intuitive, and qualitative statements about human perception in space. Therefore they seek to visualise space from a human scale perspective, and are mainly interested in exploring it in an experiential mode, so as to define the *direct impressions* created to an observer, e.g. are interested in finding out if a room *appears* spacious, dark or well-illuminated, if it gives a *sense* of visual control, or creates the *feeling* of privacy and segregation. On the other hand, spatial analysis approaches that have been developed in the framework of landscape (e.g. viewshed analysis and intervisibility calculation) and urban studies [e.g. isovists and isovists fields (Benedikt, 1979), space syntax (Hillier and Hanson, 1984), visibility graphs (Turner *et al.*, 2001)] aim to establish a more objective, formal, and quantitative approach to the study of visual experience by measuring the properties of space that may cause a certain visual impact to an observer; these are often implicit in the form and structure of the built environment and may be not be immediately perceivable by the viewer.

Though it can be argued that each approach has benefits over the other depending on the nature of questions that interest the researcher, it has to be acknowledged that each has disadvantages. On one hand, there are properties of space that cannot be fully appreciated by the subjective experience of the environment or the mere visual appraisal of rendered images, and on the other hand, the study of human cognition cannot be restricted to observations derived only from statistical and physical measurements.

In archaeological studies it has already been noted that an approach that integrates 3D modelling approaches and spatial analysis could prove beneficial (Gillings and Goodrick, 1996), as it will make use of the respective benefits that each method has to offer and balance their disadvantages. In practice however the implementation of such an approach entails obstacles, as quite often visual impressions that are derived from a three-dimensional and human scale perspective of space cannot be explored in any meaningful way by the established methods of spatial analysis that are restricted only to 2 and 2 ½[2] dimensions. The problem is much more obvious when questions on the visual experience of past environments arise in contexts that comprise of fully 3D features. Though in archaeological applications visibility analysis does not take into consideration real 3D elements, in landscape studies some successful attempts have already been made in this direction (Bishop *et al.*, 2003). Here we discuss the potential of a method of analysis that takes advantage of the ray-tracing function of 3D modelling software and the map algebra toolbox of GIS. The proposed method has been developed in an effort to address specific problems related to visual perception issues, that arise from the study of the urban remains of Late Bronze Age Akrotiri.

1 **This is a summarised version of the paper presented in CAA 2005.**

2 **Here we use the shorthand '2 ½ dimensional' to refer to the common practice of using attribute data to represent the third dimension within an essentially 2-dimensional data structure.**

2. INVESTIGATING ASPECTS OF VISUAL PERCEPTION IN LBA AKROTIRI

2.1 THE CASE-STUDY

Akrotiri, often described as the "Pompeii of the Aegean", is one of the most important archaeological sites of the region, principally due the exceptional level of preservation. The prehistoric town was buried by a huge volcanic eruption around 1646BC and brought to light in 1967. The small part of the settlement that has been excavated to date offers a variety of unique archaeological evidence, including impressive architectural remains of multi-storeyed buildings and a plethora of wall-paintings which embellished their walls. Since the discovery of the settlement many aspects of the architecture and the urban space have been studied. The issue of visual perception in the Theran built environment has been raised, especially in the context of complex architectural form and mural painting, whose essential symbolic significance is acknowledged by the great majority of the researchers. A review of the relevant literature that was published during the last twenty years, suggests that the study of visibility issues related to the positioning of the wall-paintings in the Theran urban space can offer further insights into Late Bronze Age religion (Marinatos, 1984, 81; Marinatos and Hägg, 1986), architecture (Palyvou, 2000), art (Morgan, 2000) and society.

In this context a method of spatial analysis that can handle real 3D elements could prove useful. This can more explicitly be demonstrated by testing the proposed approach on simple but characteristic examples of Theran architecture. For this purpose a mural painting, the one of the "Adorants", and the pier-and-door partition[3] at the north of Room 3a of Xeste 3[4] (Fig. 1), were chosen. In this case the occlusive function of the door jambs of the pier and door partition (all doors considered open) would only allow an individual standing or moving in room 3a to see the wall painting in partial views. It would be interesting to explore, therefore, which parts of the mural, if any, were more frequently visible from room 3[5]. As wall-paintings are artefacts whose only purpose and function were to be seen, the answer to this question can potentially shed light into conscious decisions made by the painter during the creation process as well as into the meaning of the painting.

2.2. METHODOLOGY

It is obvious that in this case it is the faces of the walls rather than their 2-dimensional footprints that are of interest. Existing methods of spatial analysis cannot sufficiently approach the problems in question; the analytical constructs developed in the framework of urbanism (e.g. isovists, visibility graphs) totally ignore 3D elements, while GIS based viewshed analysis that is only applicable to 2 ½ D models results in quantization errors on almost vertical surfaces (Fig. 2).

For this reason a methodology that can handle real 3D data and combines the analytical potential of 3D and GIS software was developed. The latter involved the following steps:

1) Firstly, a simple 3D model of the wall-painting surface and the pier and door partition of interest was created and a camera was placed in front of the wall in room 3a in such a way that would provide a view of its whole length (Fig. 1).
2) Space in room 3 was sampled using a 20x20 cm grid, whose centroids defined the viewpoints of an observer in the room.
3) Next the occlusive effects of the door jambs of polythyron on the wall were calculated by moving and placing a point light[6] at each grid centroid (Fig. 3).
4) The scene without the materials was repeatedly rendered from the camera view. 230 binary images were produced, each of them indicating the visible and non visible surfaces of the wall from a different viewpoint (Fig. 4).
5) The latter were added through map algebra operations using GIS software. In this way a cumulative map was formed that revealed the visibility characteristics of the wall.
6) Finally, the projection of the outlines of the wall paintings on this map enabled the detection of the features of the murals that were more frequently visible from room 3 (Fig. 5).

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3 **Pier-and-door partitions are structures that consist of at least three or more doors in a row (Παλυβου, 1999, 343-344) and are considered to have played an important role in controlling physical and visual access to Minoan spatial arrangements.**

4 **Xeste 3 is one of the most distinguished buildings of the settlement that is believed to have a public ceremonial function (Doumas, 1992, 128).**

5 **In this case the visibility of the wall-paintings was not explored in relation to particular paths of movement (though this is also feasible). The aim was rather to investigate the visibility of the wall painting in relation to the physical properties (geometry) of its architectural environment.**

6 **The use of point-source illumination for the calculation of visibility/invisibility has been proposed in the past by Benedikt (1979, 54) for the analogue production of isovists in architectural space.**

2.3 RESULTS AND ARCHAEOLOGICAL INTERPRETATION

Following this procedure it was concluded that, as far as visibility is concerned:

1) the most frequently visible figure of the three is the central one;
2) from the left figure the most frequently visible feature is the hand that holds the necklace (the offering);
3) From the right figure the most frequently visible feature is the gesture (the figure removes the veil and uncovers her face).

Results in this case can lead to interesting conclusions from an archaeological point of view if they are considered together with additional contextual evidence and proposed iconographic interpretations of the painting. After studying and comparing the wall-paintings of the "Goddess", the "Adorants" and the male scene that were found in Xeste 3, Morgan (2000) concludes that the directional flow of the movements and gestures of the figures within architectural space draws the viewer's attention in certain focal points on the murals that are essential for the identification of the intended emphasis in a narrative. As far as the wall-painting of the "Adorants" is concerned, she observes that although its exact significance is not clear, the focal point of the narrative is the wounded girl (central figure) (ibid. 936), as there is convergence towards the centre of the painting that is created by the direction of the movement and gestures of the other two figures. Visibility analysis corresponds with this interpretation (table), as the most important features of the painting, as far as the communication of meaning is concerned, are located on the most frequently visible parts of the wall.

Iconographic interpretation:	**Results of analysis:**
a) The focal point of the painting is the central figure (Morgan, 2000).	a) The most frequently visible figure of the three is the central
b) The flow of emphasis in the painting is conveyed through the movement/ gestures of the figures (Morgan, 2000).	b) The gestures of the figures are their most frequently visible parts.

Such correspondence could form evidence that the painter had taken into consideration the occlusive effects of pier-and-door partition on the wall, and consequently tried to emphasize certain features of the composition by placing them to the most visually prominent surfaces, so as to make the intended meaning of the painting more easily perceivable for the viewer. Though of course the exact working method of the painter cannot be known to us today, it is not hard to imagine him spending some time in Room 3, moving in space and observing his working surface, that is the wall, through the openings of the pier and door partition, before making decisions on how to illustrate his subject. It can be argued, therefore, that the application of such analysis in the built environment of Akrotiri can potentially offer further evidence to the communicative devices used by the Theran artists, as well as the flow of emphasis and the hierarchy of meaning in theran mural painting.

2.4. GIS BASED ANALYSIS OF RENDERED IMAGES

Further GIS based analysis can be used to approach more archaeological problems. By multiplying the binary rendered images with a raster that represents the figures of the wall-paintings as individual classes, the area visible (cell count or percentage) for each figure from different viewpoints in room 3 can be estimated. These data can be used as input for further statistical analysis and queries. Results of these procedures can be mapped back into space and reveal patterns of visibility that would have been hard to conceive otherwise (Fig. 6). Using different classifications for the wall-painting features questions on a qualitative basis (which specific part of the figure is visible rather than percentage of the figure) can also be made.

3. CONCLUSIONS AND FUTURE DIRECTIONS

This paper addressed the need for enriched approaches to visual space that combine the benefits of spatial analysis and VR applications. A prerequisite for the successful implementation of these approaches is the development of methods of analysis that take fuller account of the three-dimensional nature of the built environment, and the nature of human engagement with that space. The possibilities that these methodologies offer to researchers could lead to new lines of thought, new questions that can be pursued so as to give further insights to past built and natural environments. This paper presented a method of analysis that integrates the functionality of GIS and 3D rendering software and demonstrates

that the potential for enriched approaches exists in the most widely distributed software packages that archaeologists use already for a variety of purposes.
In the future, it is hoped that methodologies that can manage and analyse real 3-dimensional data structures may be further developed. We currently propose the use of voxcel-based systems or 3-dimensional vector GIS to store themes relating to environment data and results, while rendering and compositing tools more closely related to VR software may be used to process multiple locations and automatically generate highly sophisticated, fully 3-dimensional indices of visual characteristics, which relate far more closely to the human experience of place than existing viewshed, isovist or space-syntax approaches allow.

ACKNOWLEDGEMENTS

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FIGURES

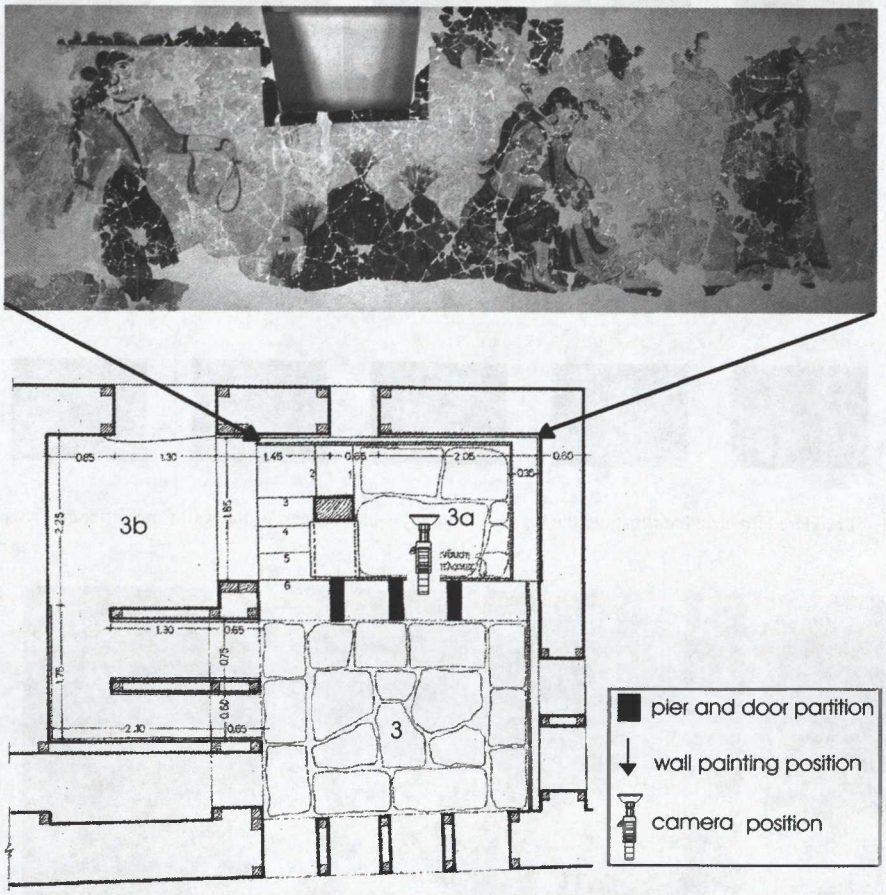

Fig. 1 – The case study: Rooms 3 and 3a of Xeste 3, the pier and door partition and the wall-painting of the Adorants. Ground plan by Clairy Palyvou.

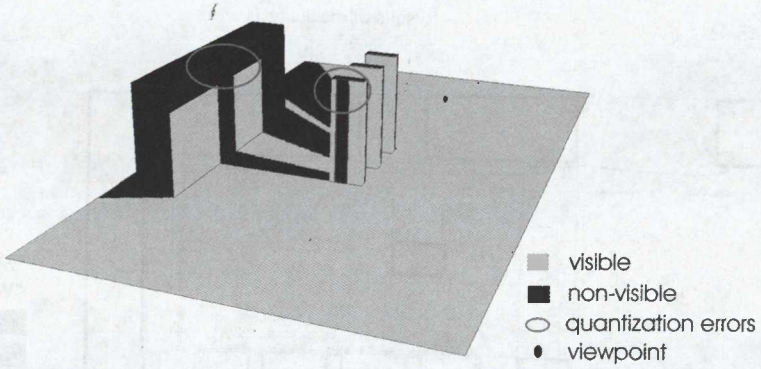

Fig. 2 – Quantization errors on almost vertical surfaces in GIS viewshed analysis.

Fig. 3 – Left: View from a camera placed at grid point 200. Right: View from the camera in Room 3a after the analogue production of the occlusive effects of polythyron with an omni light positioned at the grid point 200.

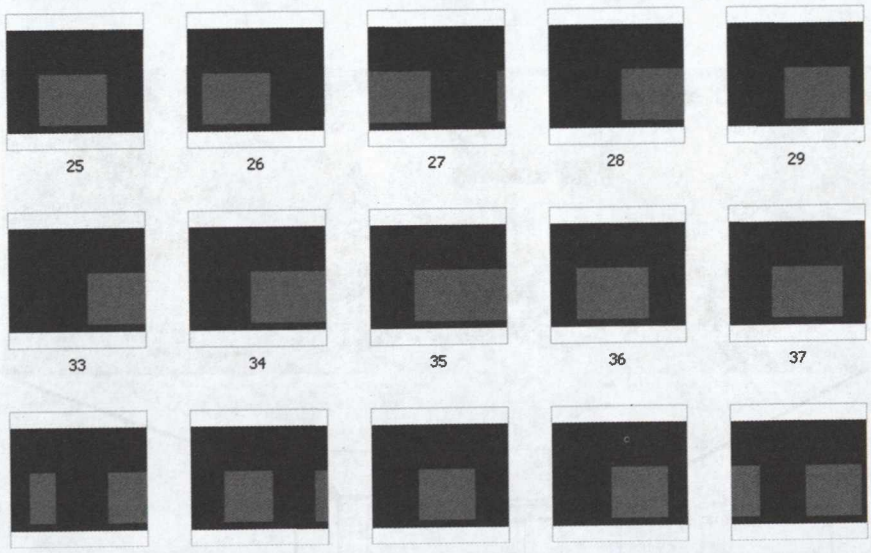

Fig. 4 – example of rendered images that illustrate the visible and non visible surfaces of the wall from different viewpoints in room 3.

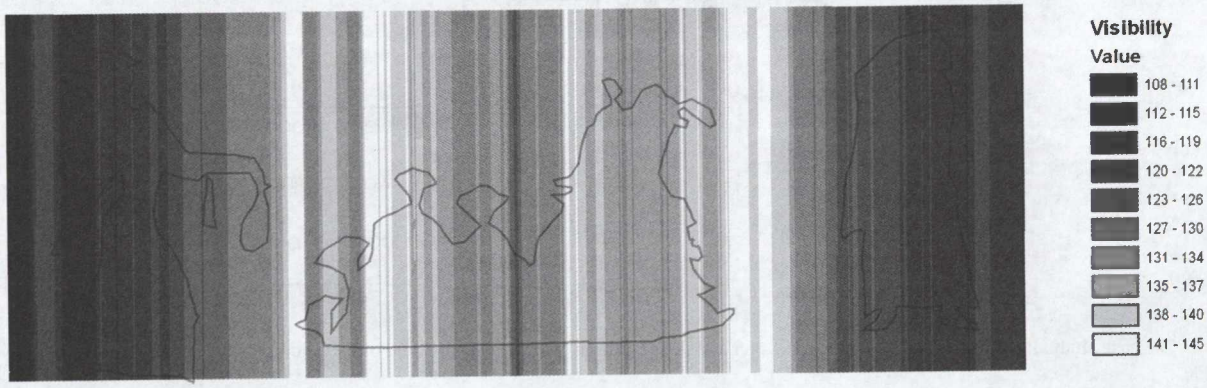

Fig. 5 – Results of the analysis.

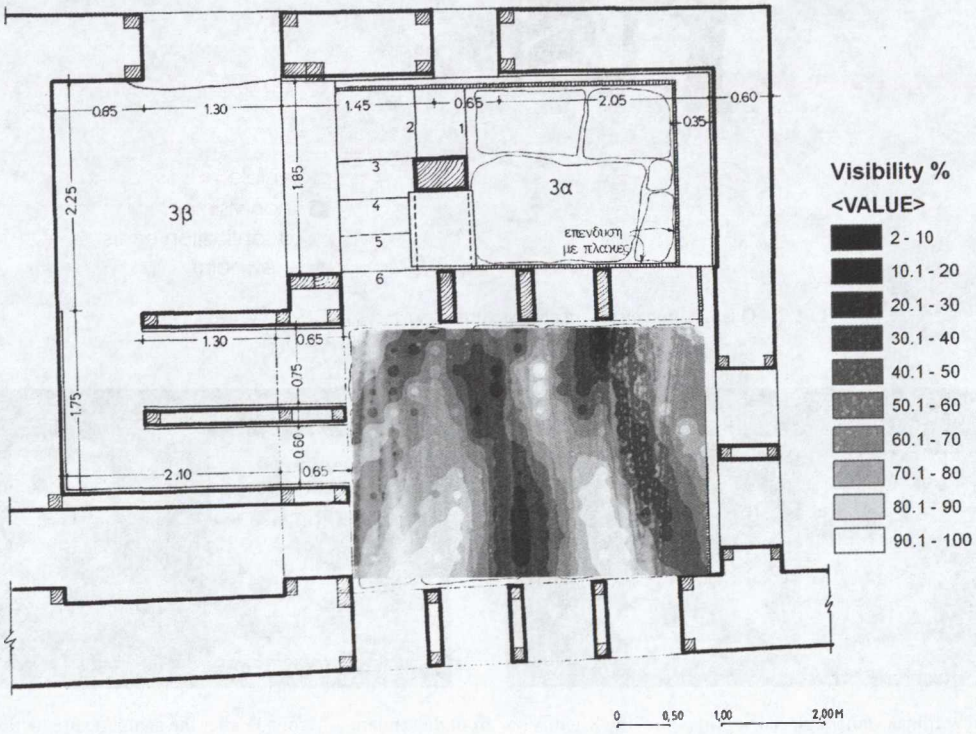

Fig. 6 – Map that shows the parts of room 3 from which all three figures are fully visible (10th class).Ground plan by Clairy Palyvou.