# From remote sensing to 3D modelling and virtual reconstructions of the Iraqi archaeological sites: the case of Hatra

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ABSTRACT: The study was developed in the *Iraq Virtual Museum* Project, that entails the construction of a Virtual Museum of the main archaeological treasures of the ancient civilisations that flourished in the territory of modern-day Iraq. The contribution of the Institute for Archaeological and Monumental Heritage of the Italian National Council of Researches (CNR - IBAM) in the project derives from the need to contextualize objects showed in the Virtual Museum, linking them to their sites of provenance; this result was achieved by recourse to satellite remote sensing and to image-based technologies. The archaeological sites analysed in the project were documented by cataloguing the most significant monuments, in terms of historical and topographical development. High resolution satellite images made it possible to observe and document the archaeological areas as they are today, and to acquire new knowledge about monuments, urban layouts and historical landscapes (archaeological and paleo-environmental data). A number of sites, monuments and objects that are more representative have been reconstructed by means of image-based modelling and rendering. For some sites, like the ancient city of Hatra, the exemplificative case study that we present here, the virtual reconstruction is partially based on satellite multitemporal images. The results of this experience show the potential of the integrated use of data from archaeological excavations, satellite remote sensing data and image-based technologies (photo-modelling and digital photogrammetry) as an effective methodology for study, documentation, analysis, reconstruction and presentation of ancient sites.

## 1 INTRODUCTION

The experience presented in this paper has been gained in the context of the *Iraq Virtual Museum* (*IVM*) Project, promoted by the Italian Ministry of Foreign Affairs and under the scientific activity of the National Council of Researches (CNR, *Consiglio Nazionale delle Ricerche*). The main goal of the project, under the scientific direction of Dr. Massimo Cultraro (CNR-IBAM), is the paragmatical construction of a Virtual platform, using the most recent advanced image-based 3D modelling (photo-modelling and digital photogrammetry), in order to lead a large public to enjoy the main archaeological treasures of the ancient Mesopotamia, after the destruction of the Baghdad Museum in 2003. The contribution of the Institute for Archaeological and Monumental Heritage (CNR- IBAM) in the *IVM* Project is strictly related to the reconstruction of some exhibition halls of the Archaeological Museum of Baghdad. In this context we have attempted to employ Virtual Reality Technology and an extensive use of multimedia, as well as communication technologies.

The Virtual Museum of Baghdad is not a real reproduction of the first archaeological collection before the definite looting and destruction. The museum represents the most creative part of an imaginary collection, which includes a selective series of artefacts transposed in digital form, each of them is related to the archaeological, as well as cultural, framework of finding. In this latter field the team operating in the CNR-IBAM has employed the most advanced technologies in studying monuments and ancient sites. It is an integrated use between traditional data coming the archaeological excavations, and remote sensing data. The investigation of the most important architectural monuments in each selected sites of Ancient Mesopotamia provides an excellent documentation in order to reconstruct the main features of an archaeological site. Moreover, the use of high resolution satellite images makes it possible to observe and to document the real conditions of the ancient sites, both as a substitutive tool for a real visit that is currently not realisable. The result of this experience, that we have firstly applied in the reconstruction of Dur-Sharrukin and of the palace of Sargon II (Cultraro, Gabellone, Scardozzi 2007), shows the potential of the integrated use of different data and technologies. The aim of this paper is to apply the same methodologies and digital technologies in the case of Hatra. The excellent preservation of the city and the total absence of a reuse of the area give us the opportunity to employ recent scientific methodologies in order to reconstruct the topographical and architectural context of this important Parthian town.

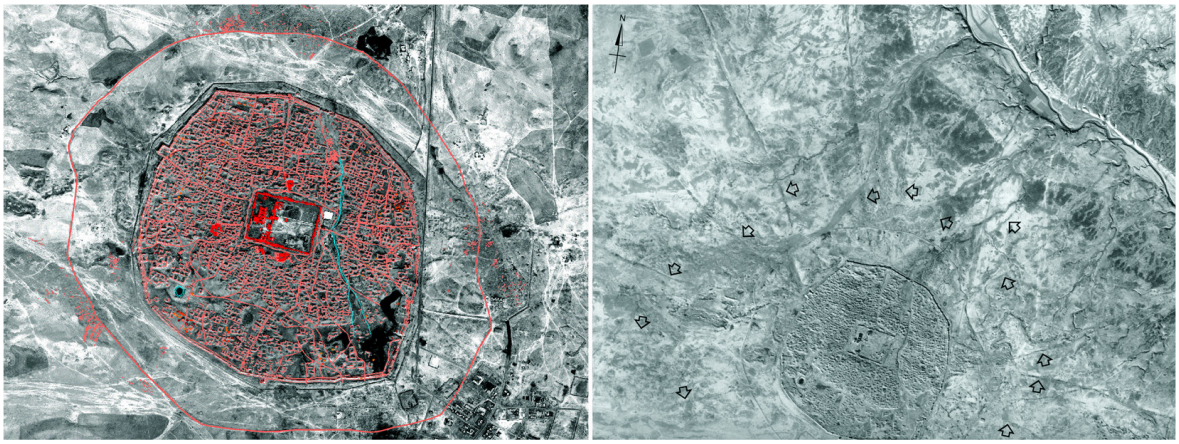
## 2 HATRA, THE CITY AND ITS BUILDINGS

The city was situated in West Jazirah (now North Iraq) between the Tigris and Euphrates, ideally located into a strategic position to control the main ways along both rivers (Venco Ricciardi 2000 and 2005, with bibliography). Hatra had the most important period between the 1st and 3rd century AD under the kingdom of Parthians until the destruction by the Sasanian emperor Shapur I in 241 AD. Roman army repeatedly attempted to conquer this strategic Parthian outpost (under Trajan in 116 AD and Septimius Severus in 199 AD), but the town always remained an independent centre. Hatra, despite is located in the semi-arid steppe, which becomes greenery in the spring, was protected from an impressive fortification system done by a stone basement and a mudbrick superstructure. The outside line (about 3 km in diameter) was built probably after the Trajan siege and served to protected the cultivated areas around the city. The inner defensive system, always constructed from mudbricks and stones, was fortified by 163 impressive towers and 4 main gates. The urban area was round planned and was crossed by a number of streets that starting from the four main gates converged towards the Great Temple in the middle of the city. Moreover, a series of minor roads intersected with the four main routes forming a circular grid.
Protected by a such impressive double fortified system, Hatra encompassed at its centre many public buildings and cult places. The fulcrum of the city was the large rectangular area (437 x 322 m), which includes a concentration of important buildings, among them the Great Temple dedicated to *Shamash*, the Sun-God. The building, which in its current form dates to the 2nd century AD, is made up of two huge *iwans* flanked by various minor structures, that were added later. The other 14 minor religious buildings, excavated by the Iraqi archaeologists, show differences of plan and architecture details with the Great Temple, reconnecting with the traditional Mesopotamian religious architecture. Finally, in the perspective of the use of high resolution satellite images, of particular interest is the wide area out of the city, where is possible to identify a road system and bridges connecting Hatra with the nearby cities, particularly with Ashur. The area where the city was build, in fact, was crossed by a large grid of trade roads from Syria to Mesopotamia, connecting Seleucia and other important city of Upper Mesopotamia.

## 3 PROCESSING AND ANALYSIS OF REMOTE SENSING DATA

For the reconstructive study of Hatra, multi-temporal remote sensing images had provided new data about its topographical layout, monuments and ancient viability in the city and in the surrounding territory. First of all, recent high resolutions images of civil satellites were acquired: particularly, an Ikonos-2 image taken in 2nd of September 2002 (Geo-Ortho Kit Bundle, with pixels re-sampled to 1 and 4 m respectively in panchromatic and multispectral mode), and two QuickBird-2 images taken in 18th of October and in 6th of March 2006 (Standard Ortho-ready products, with pixels re-sampled to 0.60 and 2.40 m). These images were used to document the modern situation of the ancient site and for monitoring the situations before and after second Gulf War; they give a general view of the entire city and its environs and allow to examine in detail all the archaeological evidences visible on the surface.
The processing and analysis of the panchromatic and multispectral images made it possible also to acquire new data about monuments, urban layout and historical landscape. In fact, they show all the structures still preserved and some of those that are partially buried or completely buried, and also a lot of archaeological elements that are hardly perceivable on the ground; for example, they clearly reveal many mounds of collapsed house-walls and even a lot of complete streets around the house blocks. All these elements were added to the archaeological map of the city; in fact, the satellite images were orthorectified on a DEM based on SRTM data, and the vectorialization of all ancient remains and traces allowed the integration and the update of the archaeological map of Hatra, with new data about ancient layout, monuments and roads (Fig. 1). So, these images can also be used for the documentation of the archaeological remains, clarifying topographical situations and even allowing fairly punctual measurements. Moreover, the new updated archaeological map was used as base plan for the 3D reconstruction of the city and its monuments.
In the satellite images is clearly visible all the circular plan of Hatra, with the external fortification about 9 km long (that closed an area of 620 hectares), with zig-zag salients, and the inner city wall about 6,4 km long (that surrounded a surface of 300 hectares). In the centre of the city is the rectangular sacred enclosure, that was divided in two sectors: the eastern, bigger (approx. 9,5 hectares) and without relevant buildings, and the western, smaller (approx. 4,5 hectares), where are concentrated the sacred edifices like the Great Temple. The symmetrical enclosure contrasts with the layout of the surrounding houses blocks and streets: some of these are fairly straight but a regular planning was not applied to them. In this area are visible some excavated structures, like the North Palace near the North Gate, the Edifice A, and the

monumental tombs of the necropolises; is also possible to distinguish the basin for water in the south-west quarter of the city.
The recent satellite images were also integrated with older remote sensing data, particularly with an high resolution space photo taken by USA reconnaissance satellite Corona KH-4B during the mission n° 1102 (11th of December 1967; ground resolution of about 1.85 m) and some oblique and vertical air-photos taken in 1920s and in 1930s (about them see Bradford 1957: 71-75, and fig. 24). These images are very interesting for the documentation of the situation before the first Gulf War and also before the start of archaeological excavations and restorations; they show the remains of Hatra even before the building of modern structures in the area of the south-eastern corner of the external city wall, that in the air and satellite photos appear more preserved that today. These images show more evident than recent satellite images the traces of many ancient routes that radiating from Hatra ("hollow ways"), that often remained in use for millennia; a study based on the integration of Corona satellite photos taken in August 1968 and in December 1969, and the Tabula Peutingeriana had evidenced the role of the city as an important meeting point of trade routes crossing the eastern Jazira, principally with a NW-SE direction, connecting the Arsacid capital Ctesiphon and lowland Mesopotamia in general with Armenia and the eastern border of the Roman Empire (Altawell, Hauser 2004). Particularly, the Corona KH-4B photo of 1967 (Fig. 2) shows a lot of traces of short distance roads (connecting the city to neighbouring sites and little villages) and long distance routes, like that in ESE direction that connected Hatra to Ashur. All the elements that appear in these air and satellite photos were also georeferenced in the new archaeological map of Hatra.

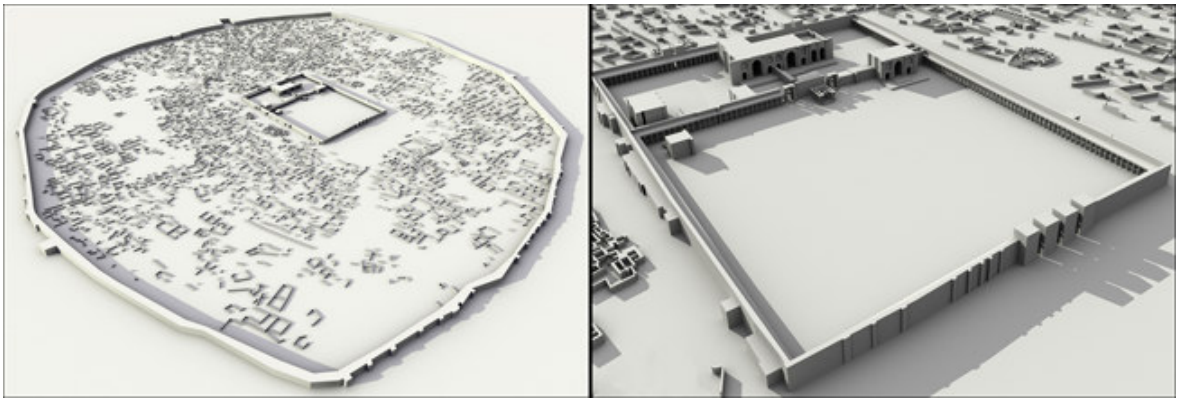


*Figures 1-2. Orthorectified QuickBird-2 image with vectorialization of the archaeological evidences (in pink); plans of some monuments are also georeferenced on the image (in red). Corona KH-4B photo of 1967: the shadows indicate traces of ancient roads radiating from Hatra in west, north and east direction.*

## 4 THREE-DIMENSIONAL RESTITUTION: PRELIMINARY RESULTS

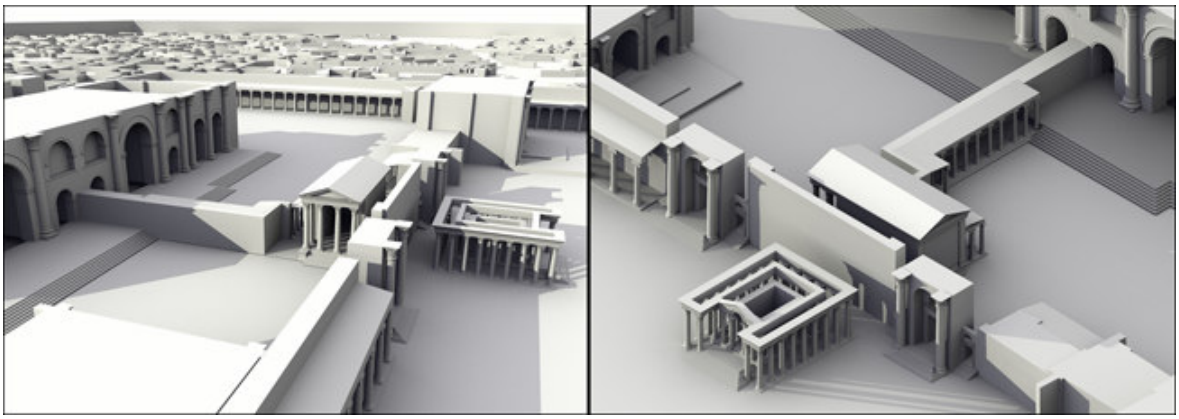
Studying a monument with a view to its reconstruction involves combining historic and humanistic knowledge with the use of modern information technologies, not just to understand and interpret ancient building complexes, but also – and especially – to transmit the knowledge acquired to a broad and heterogeneous public via appropriate media at varying levels of interest and understanding. We believe that this is an exciting time for archaeology, which is increasingly in the public spotlight, thanks (among other things) to the communicative power of the tools that are now available. These tools make it possible to recreate not only shapes and materials, but also to capture the atmosphere of daily life in ancient times. Evidence for this may be seen in the enormous growth on the web of virtual and thematic museums, of virtual collections and galleries, all designed to promote knowledge of archaeological and monumental heritage items by means of these new technologies. The reconstructive study of the city of Hatra (still in progress) is clearly a highly challenging and complex task, and it will be some time yet before the studies and data processing reach a point where they can provide a plausible and complete visual representation of the urban layout. The city was the crossroads of important caravan routes, but it was also the crossroads of a number of religions – Semitic, Greek and Mesopotamian. The traces of the ancient city, which are still partly visible *in situ*, tell the story of this blend of cultures and styles, particularly admirable in terms of the formal characteristics of the temples. Here, Hellenistic and Roman architectural influences are superimposed on decorative elements of oriental origin, giving rise to a style of

architecture that is truly exceptional, and has quite rightly been included in the UNESCO list of world heritage sites.



*Figures 3-4. 3D models of the city and the internal walls, and of the sacred enclosure.*

The 3D restitution that we propose here represents merely the starting point for the formulation of hypotheses, which will obviously require further studies and excavations. However, it has been possible to start tracing the layout of the city using a new methodological approach that combines humanistic and technical-scientific knowledge. The 3D models were obtained by comparing the results of the analysis and vectorialization of satellite images, the information from past excavations, and the evidence from the site in its current state. The images shown here highlight the presence of densely-packed residential buildings across much of the city. This phenomenon, knowledge of which was previously rather limited, is observed around the great monumental buildings in the central area. The satellite images also show that the streets of the city were not arranged in a regular grid and that the circuit of defensive walls included towers at regular intervals. These initial results will be of help to the reconstructive study as it proceeds with the recognition of individual dwellings and the city's main gates, helping to provide a clearer picture of the arrangement of the road network both inside and outside the city.



*Figures 5-6. Particulars of the 3D model of the sacred enclosure.*

## 5 ACKNOWLEDGEMENTS

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## 6 REFERENCES

Altaweel, M.R., Hauser, S.R. 2004. Trade routes to Hatra according to evidence from ancient sources and modern satellite imagery, *Baghdader Mitteilungen*, 35: 59-86.

Bradford, J. 1957. *Ancient Landscapes. Studies in Field Archaeology*, London.

Cultraro, M., Gabellone, F., Scardozzi, G. 2007. Integrated Methodologies and Technologies for the reconstructive study of Dur-Sharrukin (Iraq), *XXI CIPA Symposium (1-6 October 2007, Athens)*, Athens, 253-258.

Venco Ricciardi, R. 2000. Hatra. Presentazione del sito, *Topoi* 10: 87-110.

Venco Ricciardi, R. 2005. Hatra, *Enciclopedia archeologica*, *Asia*, Roma, 309-311.