

Multi-Scalar GIS at Merv, Turkmenistan: Bringing it All Together

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Abstract

Since the designation of Merv, Turkmenistan as a UNESCO World Heritage Site in 1999, multiple archaeological projects have aimed to disentangle the complex heritage of this unique urban landscape. The main focus of recent studies, and indeed the target of this study, is the early Islamic city of *Sultan Kala*. The visible urban landscape is currently being investigated using GIS and high-definition 3D documentation (laser scanning) of the extant architecture. The Ancient Merv Project now aims to integrate this data and previous work to form a complete and comprehensive record. This allows for isolated monuments (documented via high-definition survey) to become part of a wider landscape study (GIS), whilst facilitating detailed conservation studies and monitoring of erosion of the earthen remains. The Ancient Merv Project aims to educate and inform on a local, national, and international level, making the user interface an important part of the digital archaeological record.

Keywords

Laser scanning (high-definition survey), GIS, Islamic cities, Total Record, earthen architecture, conservation

1. Introduction

Merv, Turkmenistan is a large complex archaeological site and has been the subject of a variety of research projects with vastly different aims. Even prior to the creation of the ‘International Merv Project’ in 1991 (Herrmann 1999) (predecessor to the ongoing Ancient Merv Project), archaeologists rigorously chased specific themes amongst the cities’ ruins spanning over nearly two millennia of occupation. Following technological advances in the field, recent aims of the University College London research team have experimented with using remote technology and high definition survey to document, investigate and manage Merv’s heritage. Unlike many of the previous studies conducted, however, it is hoped that new approaches to understanding the urban landscape can be the result of holistic and integrated investigation combining interdisciplinary approaches at the site.

Merv has been a fulcrum of Silk Route trade throughout its history. Positioned on what is effectively the gateway between East and West, a plethora of cultures over two millennia have influenced this unique and complex urban landscape. Founded around the 6th century BC the earliest cities of *Erk Kala* and later *Gyaur Kala* occupy the Eastern half of site (*Fig. 1*). Following the Abbasid revolution in AD 784 Islamic occupation in *Gyaur*

Kala was relocated to a new adjacent city, *Sultan Kala*. Repeatedly exchanging hands through the tumultuous early years of the Islamic caliphates, *Sultan Kala* was eventually abandoned following the Mongol sack of AD 1221 (Williams 2007, 45-47). At its zenith it is estimated that the city housed around 250,000 people (Williams, pers. comm.). Current research is headed by the Ancient Merv Project – a collaboration between the Institute of Archaeology at University College London and the Turkmenistan Ministry of Culture. Recent work at the site includes excavation, walkover survey, mapping and exploring the urban landscape with satellite and aerial photography, capacity building for site management and conservation (part of which now includes high definition documentation [HDD]) and educational outreach.

2. A ‘Total Record’

This paper investigates two independent but connected research projects conducted at Merv in autumn 2007. The first is a new initiative using high definition three-dimensional survey (laser scanning) to document the extant earthen architecture within the World Heritage site. With the financial and logistical aid of CyArk (<http://www.cyark.org>) and Plowman Craven and Associates (<http://www.plowmancraven.co.uk>), a laser scanner was brought to Merv for the

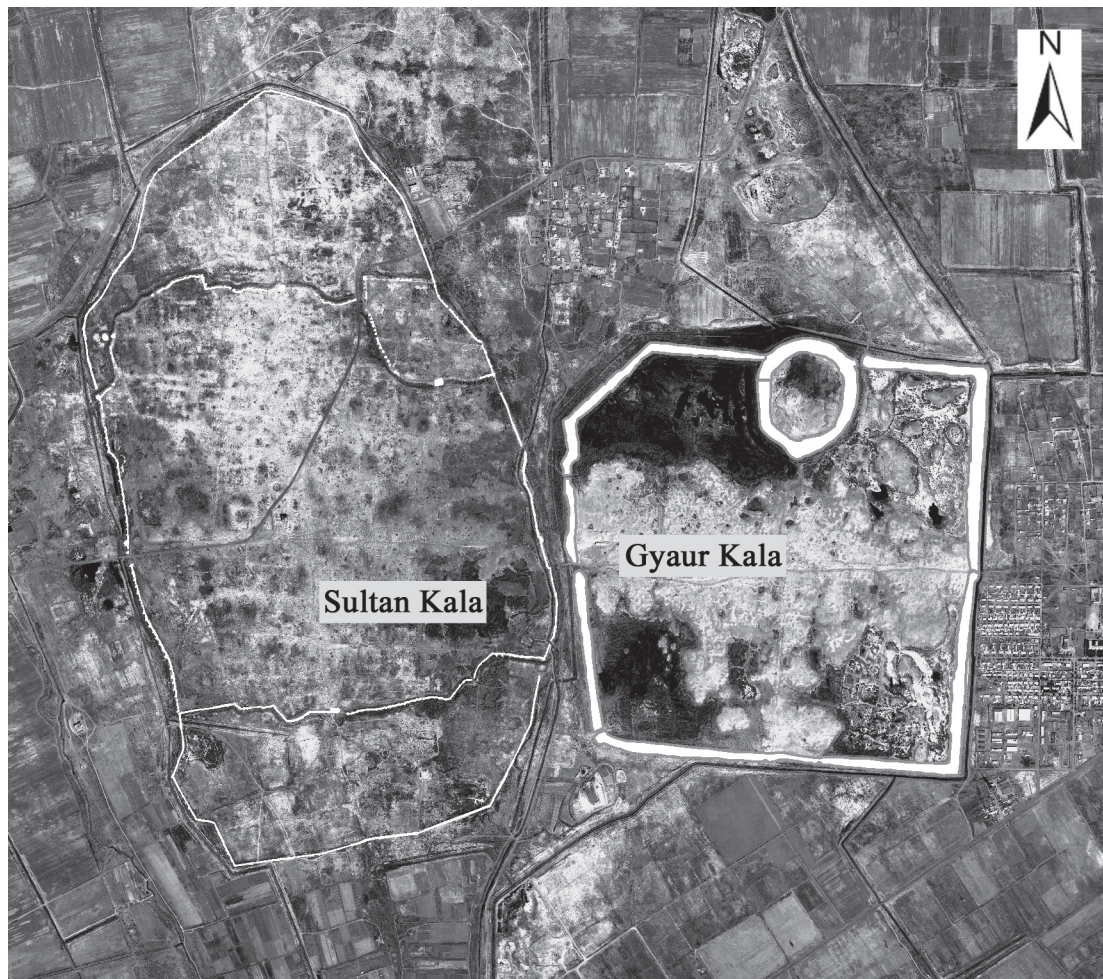


Fig. 1. Map of the ancient cities of Merv showing the original Gyaur Kala with its citadel Erk Kala, and to the west the Islamic city of Sultan Kala with its northern and southern suburbs, and the Shahriyar Ark (citadel) in the north-east corner of the city.

purpose of documenting buildings designated most at risk. It is proposed that as well as providing a 'total record' of what is a rapidly disappearing resource, the data will serve to monitor erosion processes of the

structures, reveal new details of their construction, and provide an accessible means for communicating the site's heritage. In total seven structures and three excavation trenches were laser scanned, photographed and georeferenced, the data from which is currently being processed (Fig. 2). All documentation was conducted using a Leica ScanStation at a minimum lateral resolution of 6mm, photographed with a Nikon D80 10.2 Megapixel digital SLR and georeferenced with a Leica 1200 GPS and total station.

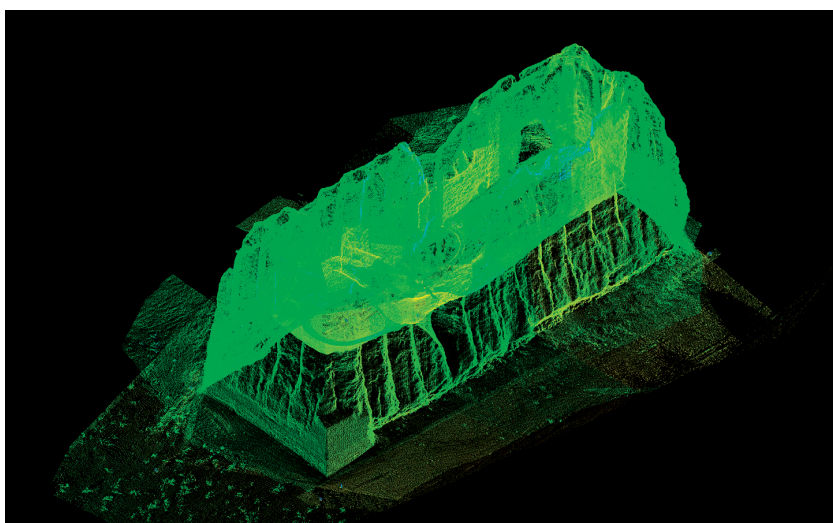


Fig. 2. Laser scan point cloud of the Kepter Khana in the Shahriyar Ark, one of the extant monuments documented for the Ancient Merv Project in 2007.

The second research project is the remote mapping of *Sultan Kala*, the Islamic city occupying the eastern half of the archaeological Park. This ongoing research aims to combine aerial photographs, satellite images, topographic maps and ground reconnaissance to form

a plan of the urban landscape. Acquiring an accurately georectified IKONOS image in 2001 formed the basis of this study, which has evolved into a geodatabase catalogue of the numerous streets, structures and courtyards visible as lines on the remote data (Fig. 3). Ground truthing supported GIS mapping, which now includes reflexive interpretation influenced by previous excavation and survey data. All of the remote data was traced using the ArcGIS 9 suite and the data held in a 'Personal Geodatabase' (ground-truthing used the equivalent hand-held PDA version ArcPad). Attribute data contained information about the interpretation of features, a certainty value detailing clarity, geometric measurements and data on the images referenced.

Whilst both of these projects stand to achieve their independent aims, it is proposed that the convergence of data gathered can serve to be mutually beneficial. Although the technologies are by no means easy to combine, taking an archaeological perspective we hope to investigate approaches to integrated multi-scalar data, reflecting its impact for understanding and communicating heritage. It is by combining these technologies that we begin to approach what might be termed a 'total record'.

3. Archival unity

One of the major aims of integration is to achieve what we have termed 'archival unity'. That is to say, enabling distinct datasets to be inter-usable through a series of compatible recording formats within a GIS framework. This is to several ends:

At many archaeological sites, the level of organisation varies depending on the data collection methods. For example highly standardised context records may sit alongside less rigorously managed digital photographic data or pottery analysis; often leading to accidental data loss or incompatibility. We propose that even using simplified models of the laser scan data, it is possible to manage projects centrally through a GIS framework. Combining the data from satellite mapping and plans derived from the laser scanned buildings we have been able to assign similar interlinking attributes between extant and inferred structures. It is possible to view all of these elements together, shown in Fig. 4 combining

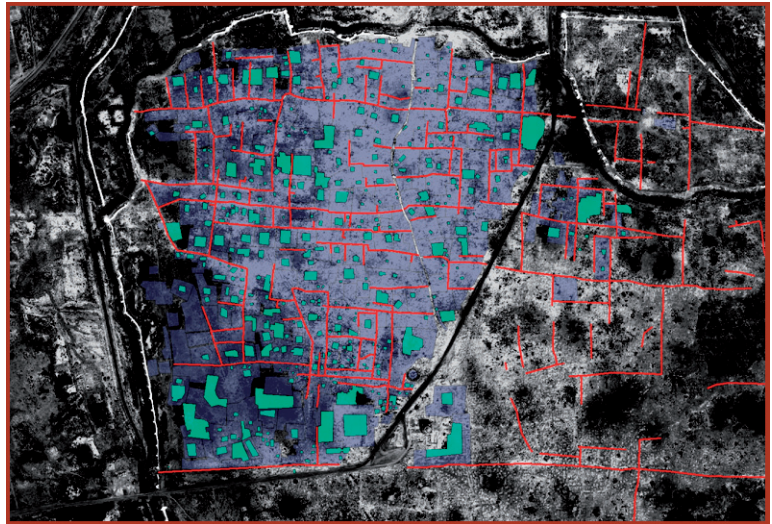


Fig. 3. GIS mapping of streets, courtyards, and buildings visible from remote data (IKONOS satellite imagery) within Sultan Kala.

the DEM, point clouds and scanner information, 2D plan, and photograph data.

Increasingly international archaeological data repositories require specific standards of data (for example, the Archaeological Data Service [York, UK]), although currently there is no accepted international format for many types of data. If site data is to be managed in a designated archive, it is important that all of the data meets the archive service standards. It is currently proposed that only the HDD data set for Merv be stored centrally through the CyArk online community. Unless this data is also kept alongside the rest of the archaeological record, there is a high risk that the information may become increasingly disparate and de-contextualised.

Usability of a so-called 'integrated record' is an equally significant factor. Simply overlaying the point cloud data on a DEM of the city can lead to a more iterative interpretation process, based on a wider understanding of the urban landscape. Hyperlinking in the GIS provides another tool to access variable format data such as the photographic archive. This is applicable to other forms of digital recording such as excavation data, condition assessments and even potentially interactive VR environments. Throughout the integration process, it is important to maintain a transparent record including relevant metadata to allow for additions and expansions.

4. Analysis

As well as promoting the overall usability of the archaeological data from Merv, integrating laser scan and GIS data lends itself to specific analyses.

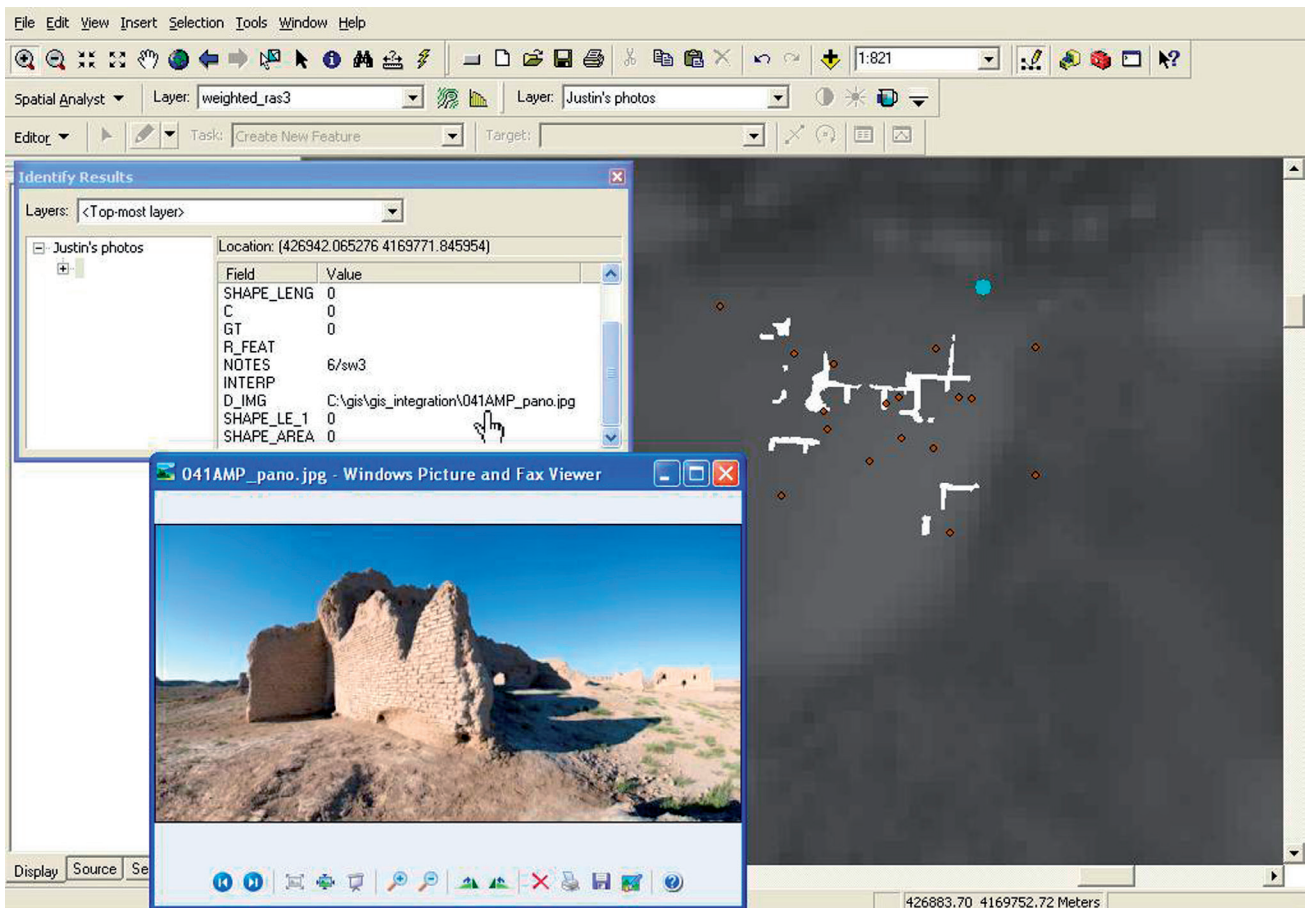


Fig. 4. Screenshot of ArcGIS software showing the potential linkage of various attributes alongside the imported point-cloud-derived plan of the palatial complex within Shahriyar Ark.

Hydrology is a major theme which we are exploring as a means to target conservation efforts and highlight problematic areas. Fig. 5 shows a basic hydrological model of the *Shahriyar Ark* (or citadel) of *Sultan Kala*, highlighting pits and basins. The plan of the *Kepter Khana* (and the associated palatial complex to the south-east) has been derived from the georeferenced HDD data, which can be viewed either aerially or as a 3D interactive environment. In this example, one topological depression corresponds to the north-western corner of the extant *Kepter Khana*, a zone which has suffered severe erosion in the past warranting intrusive conservation (as seen in Fig. 6). Also visible is the continued erosion at the base of the monument owing to a high level of ground water, an issue that must be addressed as part of a sustainable management plan.

One of the major aims of the HDD project is to monitor the annual erosion of earthen architecture at Merv. Integration can serve to enhance the models of progressive weathering and examine it on a wider scale as well as providing information on sheltered/exposed areas and other contributing factors.

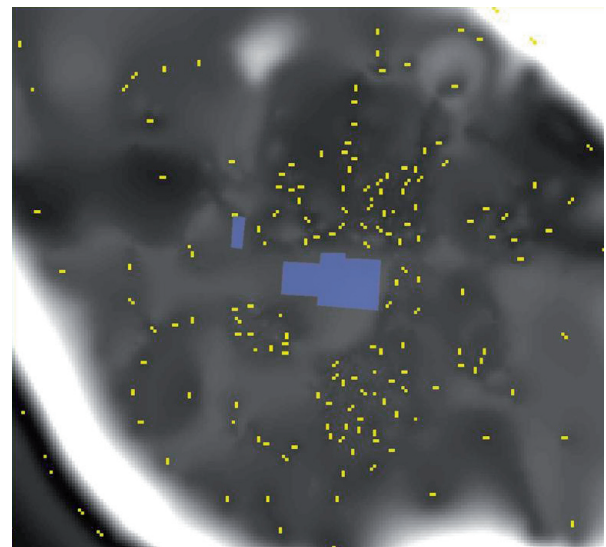


Fig. 5. Plans of the Kepter Khana and associated palatial complex in the Shahriyar Ark of Sultan Kala, superimposed over a hydrologically modelled DEM highlighting topological basins.

With the use of 3D modelling programmes such as *3D Studio Max* and *VRMesh*, potential developments at the site can be understood in terms of their impact on a micro and macro scale. In a dynamic and



Fig. 6. Reconstructed corner of the Kepter Khana in the Shahriyar Ark of Sultan Kala, where new degradation through water absorption is becoming apparent at the base of the monument.

highly politicised environment, the archaeological park changes year-on-year, demonstrated by Fig. 7 of the *Greater Kyz Kala*. The staircase visible was inserted through an eroded hole in north wall between 2006-

2007, with great impact to the integrity of the structure and visitor management. Had this intervention been modelled using HDD/GIS prior to its insertion, it would have been possible to understand better its effects on the archaeology and visitor experience. Other human impacts that may be understandable through an integrated system are the continued spread of intensive agriculture and expansion of modern graveyards within the site.

5. Implementation

One of the major hurdles still to be overcome is the sheer size of HDD datasets (in this case the largest single building containing over 159,000,000 points) often rendering it impossible to combine HDD with landscape level GIS. We have currently circumnavigated this issue by significantly reducing the number of points per building, minimising file size but at a cost to the accuracy of representation.

Furthermore, in order to display point cloud models effectively, it has been necessary to mesh the items, with varying degrees of success. Developing a more effective method for displaying the data is an issue high on our agenda, balancing quality of data



Fig. 7. The Greater Kyz Kala monument, showing a metal staircase inserted through an erosion hole in north wall in Spring 2007.

alongside limited resources (including computer power) and time-effectiveness.

We would also like to improve user interface elements of the integrated system, harnessing potentially powerful educational and interactive tools such as VR and immersive site exploration. Doubtless one of the possible end-products of our approach may be to provide interpretive reconstructions of the HDD buildings in their urban environment as a communication resource. This is currently hindered by the almost complete absence of internet access in Turkmenistan, which arguably relegates high-technical approaches to communities outside of those in the immediate site setting. The Ancient Merv project aims to overcome this through a rigorous programme of local education through teachers' handbooks and open days to disseminate knowledge about the site.

For those regions with easy access to Information Systems, the choice of software is an important concern. At present we have trialled this process using ArcGIS 9 for a number of reasons:

- Its widespread use across academic disciplines and even into the public sector.
- Its easy interface with commonly used programs and user-friendly approach.
- The large corporate establishment that is ESRI is able to maintain an ongoing data management programme providing upgrades and version controls unlike some bespoke software solutions.

Understandably open source choices would enable a wider audience to access and interact with the data for free, however through a casual survey of academic and professional users it would appear that at present most have a greater reliance upon premium packages such as ArcGIS. As archival standards for GIS products become more stringent, it is expected that these will dictate which programmes are the accepted platforms for spatial data.

Finally to return to a 'total record', it is not possible to compile every single piece of data for this vast archaeological landscape as the record is as extensive as it is complex. However, we propose that adding together current elements of investigation can have an important bearing on site interpretation and management. 'Drawing the line' based on data needs would seem appropriate, although potentially short-sighted if underestimated. In this regard we aim to provide a system that is readily updateable and a framework to which new data can easily be

annexed. Increasingly affordable HDD heralds the advent of laser scanned excavation – the next step in providing total data capture. Meanwhile managing millimetric point clouds within GIS keeps our focus firmly on contextualising the data, applying a holistic approach.

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