

The Warka Environs Aerial Survey

Aerial 3D Photogrammetry of the Ancient City of Uruk and its Environment

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Introduction

The *Warka Environs Survey* (WES), is an archaeological project hosted at the Oriental Department of the German Archaeological Institute (DAI), can now present a large-scale and detailed 3D model of the ancient city of Uruk and its environment based on aerial imagery. The scientific exploration, as well as preservation and presentation of the site benefit in manifold ways from this detailed 3D photogrammetric documentation. The famous archaeological site is a symbol for the development of urban culture, which was one reason for its recognition as a World Heritage Site by the UNESCO in 2016 (Al-Lami 2014).

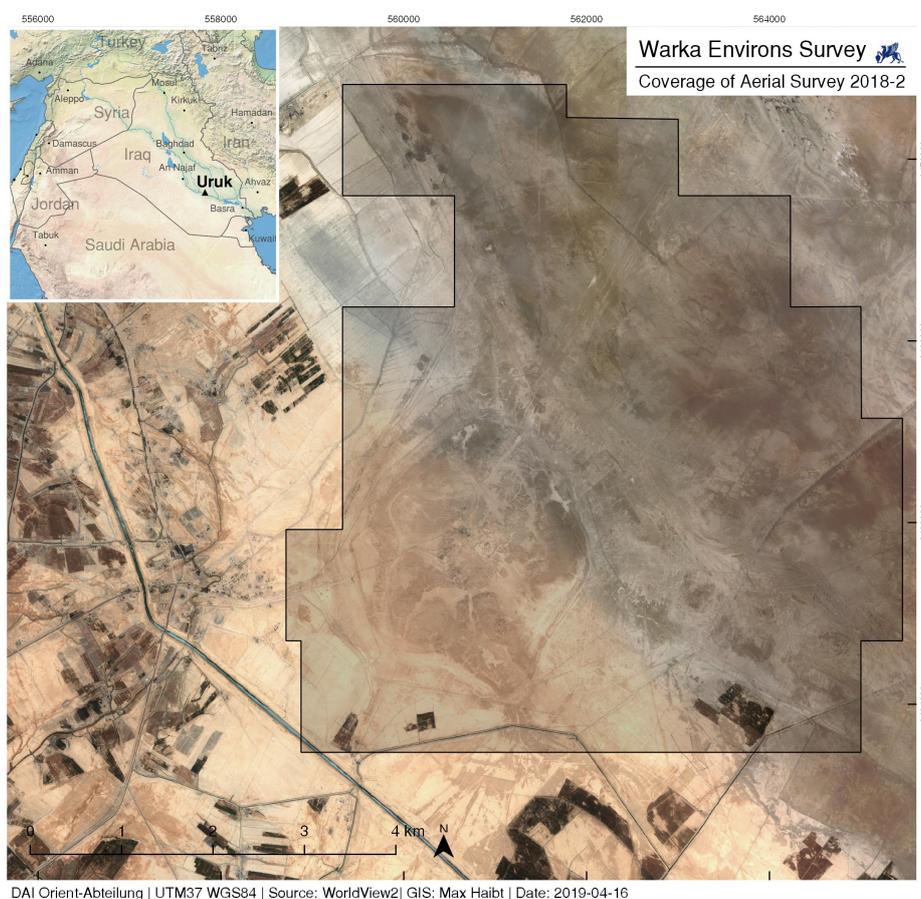


Fig. 1 Map showing the site of Uruk-Warka and the coverage of the aerial survey (© DAI Orient-Abteilung).

For more than one hundred years the site has been explored by archaeologists who brought to light remarkable material culture which preceded all known Mesopotamian cities and showed clear signs of an urban lifestyle (Nissen 2003). This period and material culture of the 4th Millennium BC was named after the city itself – the Uruk-Period. From this time on the city was settled for over 5000 years, leaving tremendous amounts of human remains on a vast archaeological landscape. The exceptional size of this archaeological site and its many settlement layers are challenging for research and conservation. The Republic of Iraq and

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its *State Board of Antiquities and Heritage* have taken on this challenge, supported by the DAI, which continues its long-term engagement on the site.

Method

The 3D model covers the city and the surroundings amounting to a total surface of 40km² (see fig. 1). The alluvial plain is mostly flat, some meters above sea level, only the ruins of the city appear as an extended conglomeration of hills arising to maximal 30m above the plain.



Fig. 2 a) Home position of the UAV; b) Ground control station at the excavation house (© DAI Orient-Abteilung).

The Survey mission was conducted at a height of 260masl, flying with a 'Vertical Take-off and Landing' Unmanned Aerial Vehicle (UAV) – the *DeltaQuad Pro*² (see Fig. 2). The *DeltaQuad* can fly 90km in one hour flight time per battery load. Overall 30,000 images were captured using the light-weight and full-frame camera *Sony RX1R2*. The ground resolution of the images comes down to 3cm per pixel. They were recorded in raw-format to preserve the highest colour-depth possible. Cloudy and late-day images were adapted to the exposure of sunny day-light images and developed into high-quality Jpegs for import to 3D photogrammetry software.

The model was processed using *Reality Capture*³ (see Fig. 3), which is known to be the fastest 3D photogrammetry software on the market. The size of the project made it necessary to split the images into clusters, which had to be aligned separately and then merged to one component in the subsequent step. Dense reconstruction was performed upon the entire component, although processed in small parts to allow highest quality reconstruction. Actual working with these results takes place in *Qgis*⁴, which is why 2D ortho projections and 2D elevation maps are the most important product generated from this model. It should be mentioned that it is only due to the advancement of UAV technology and 3D software that this project has been possible. This paper explains the entire technical production of the model and highlights especially the difficulties of large-scale 3D photogrammetry.

2 Manufactured by Vertical Technologies, Badhoevedorp, the Netherlands, <https://www.deltaquad.com/>

3 Developed by Capturing Reality s.r.o., Bratislava, Slovakia, <https://www.capturingreality.com/>

4 QGIS Geographic Information System. Open Source Geospatial Foundation Project. <http://qgis.osgeo.org/>

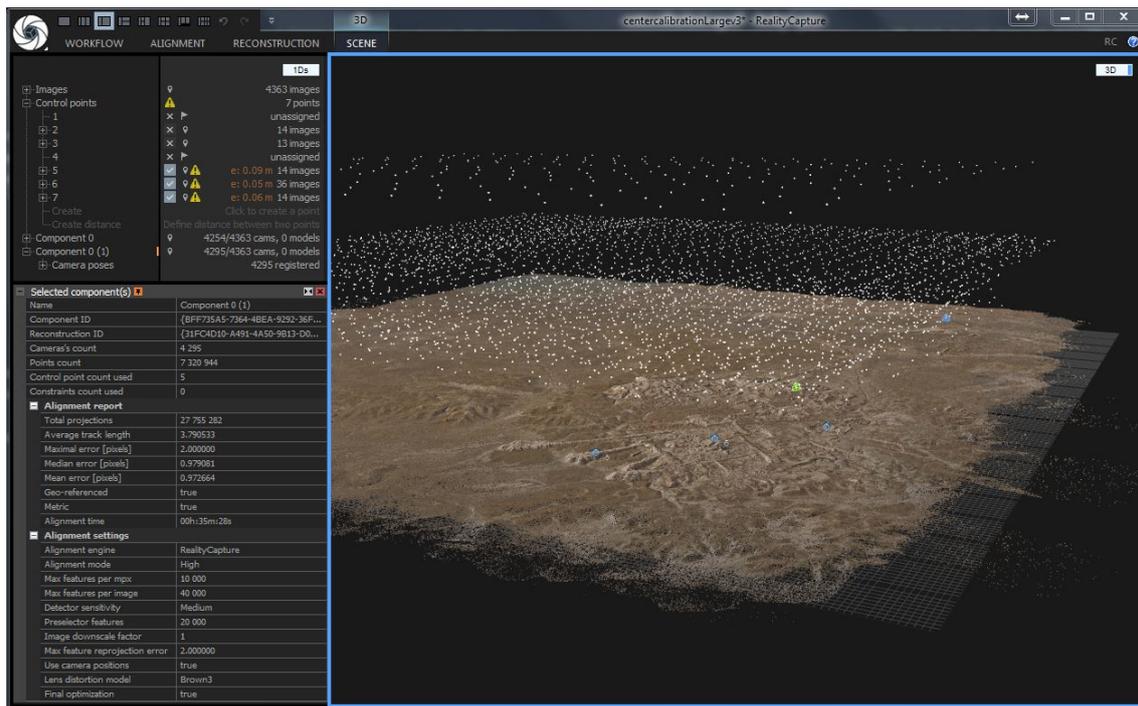


Fig. 3 Aligned images in Reality Capture (© DAI Orient-Abteilung).

Archaeological benefit

Researchers can discover archaeological features remotely on the entire site. They make use of the bird's eye perspective to understand water-canal systems, map out artefact clusters and detect architecture.

The special focus of the WES project is the suburb area, outside the early dynastic city-wall of Uruk, which has never been surveyed systematically, until now. The surface of the city inside the wall has been surveyed intensively (Finkbeiner 1991) and the entire region, the Warka basin, has been surveyed roughly (Adams and Nissen 1972). The investigations in the immediate surrounding, within c. 3km distance to the city-wall aim at answering questions about the interaction between the urban center and its urban environment. Specifically:

- How where urban spaces produced and maintained ?
- Where was the outer limit of the city during different periods and what was the difference between inside and outside?
- How did environmental change (natural as well as social changes) affect the development of the urban center and its suburbs?

Remote sensing is accompanied by ground surveys, including artefact collection in designated sampling areas. The collected artefacts serve as functional and chronological indicators and their spatial distribution in the suburbs of Uruk provides the data base upon which will be argued.

Aerial survey and ground survey optimize each other. With remote sensing different types and densities of features and objects can be mapped efficiently. A comprehensive map of archaeological surface features exists before the survey-team has gone in the field. Remote sensing prior to ground survey multiplies the understanding of the space in focus and raises specific questions. The ground survey in this, can be planned in order to answer these questions.

Clusters of objects, for example heaps of pottery sherds, slag and bricks can be mapped remotely, because any object larger than a tennis ball can be recognized on the imagery. However, ground-truthing is

necessary to determine the character of certain features. It is, for example, important to know the composition and density of objects in those clusters, and therefore close-up pictures and samples are necessary. Other features, like the extended remains of canal-systems and rivers are much easier mapped remotely, although investigations on the ground are necessary to determine the stratigraphy where canals are cutting across each other.

The ground survey is thus collecting more detailed information about the surface which can also be used to validate remote classification and thus helps to improve it in the long-term.

Of course, to align the spatial documentation from ground survey with the aerial 3D model both need to be georeferenced accurately.

The global coordinates of the model were measured by applying, recent technical innovations: Camera positions were measured when images were taken, using the low-cost D-GNSS receiver *Reach M+*⁵ on board the UAV. The 3D model was then georeferenced based on the camera positions, without the need to measure ground control points. The same method is applied during ground survey to produce accurately geotagged, close-up imagery of the features.

Presentation and conservation of the cultural heritage at Uruk is yet another task which greatly benefits from the comprehensive spatial documentation of the site. One example: Parts of the architecture which was once revealed by archaeologists in the 20th century, i.e. the 'Steingebäude' below the Anu-Ziqqurat, is eroding due to run-off water backlogged in depressions. The detailed digital elevation model makes possible water flow calculations and subsequent water channelling in the field, to prevent further damage.

This paper will present the methodological aspects of modelling such a large landscape and how research and conservation can benefit from the results.

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⁵ Produced by Emlid <https://emlid.com/reach/>