Assessing Cultural Heritage in post-conflict Iraq

The case of Ashur

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Abstract: Whilst archaeologists have worked in post-conflict zones for decades, they have rarely focused attention on how the circumstances of conflict affect their fieldwork. In recent years, ISIL attacked but could not destroy the World Heritage site of Ashur in northern Iraq. Today, the situation on the ground remains volatile in the aftermath of the war. This article will outline the challenges facing archaeologists working in post-ISIL communities in northern Iraq, using Ashur as a case study. With planning, persistence, and most importantly local co-operation, the project enjoyed success on a limited budget. Aerial reconnaissance and ground survey combined to demonstrate that the World Heritage site was significantly larger than previously recorded. The project team combined subject matter expertise with local IT experience in order to the create a customized AI algorithm using the Inception v3 model that successfully distinguished between archaeological features with an average of 87.7 % accuracy. After outlining the future of AI at Ashur, the article will conclude with a discussion of lessons learned for post-conflict archaeology in Iraq.

Keywords: *post-conflict archaeology—Iraq—cultural heritage—Ashur—artificial intelligence*

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Introduction

In ideal circumstances, modern technology allows for significant fieldwork at low-cost in almost any location on Earth. The project's initial goal was to document ISIL's destruction of Ashur in detail, including verifying reports of looting and other site modifications that ISIL might have made to prepare for the attack of coalition forces. The American School of Oriental Research's Cultural Heritage Initiative (ASOR CHI) verified reports that ISIL forces attempted to destroy the Tabira Gate, and succeeded in their destruction of the local State Board of Antiquities and Heritage (SBAH) offices, the on-site museum, and the protective cover for the Assyrian royal tombs (Danti et al., 2015), yet new field research showed that initial reports of a larger program of ISIL looting or trenching for self-defense at the site appear to relate to other mounds further south, not to Ashur itself (Danti et al., 2016). Rather than focus on the verification and falsification of past reports about ISIL's activities, this article will reflect on the myriad challenges to applying technology in post-conflict Iraq as well as solutions for projects running on smaller budgets in remote communities using Ashur as a case study.

The Situation of Post-Conflict Ashur

Given that the World Heritage site of Ashur was liberated in late 2015, its liberation forms one of the earlier stages of the Coalition's campaign against ISIL-held territory in northern Iraq. ISIL affiliates in neighboring rural districts still conduct sporadic attacks on individuals though these attacks have decreased significantly after the October 2017 counter-terrorism operation in Hawija (Flood, 2017)[1] and the September 2019 coalition air strikes on Qanus Island (Stockton, 2019), located approximately 15 km upstream of Ashur (modern Sherqat). There are still isolated conflicts in the Khanuka mountains (15 km south of Ashur) between ISIL affiliates and Iraqi security forces (ISF) and locals report that the greater Jebel Makhmur region contains ISIL fighters driven out of Qanus Island, which prohibits night-time travel from Erbil to the region (Fig. 1). In contrast, the city of Sherqat and the archaeological site of Ashur are safe for now. The main challenges today are systemic problems of inadequate infrastructure and investment that lead to avoidable deaths such as 128 casualties from the sinking of a Mosul Ferry on March 21st, 2019 (Abdul-Ahad, 2019); or an unreported capsizing of a local ferry at Sherqat in May 2019 that ultimately killed 4 young women. They died as a result of the spring floods, yet they would have lived if the bridge over the Tigris had been completed.

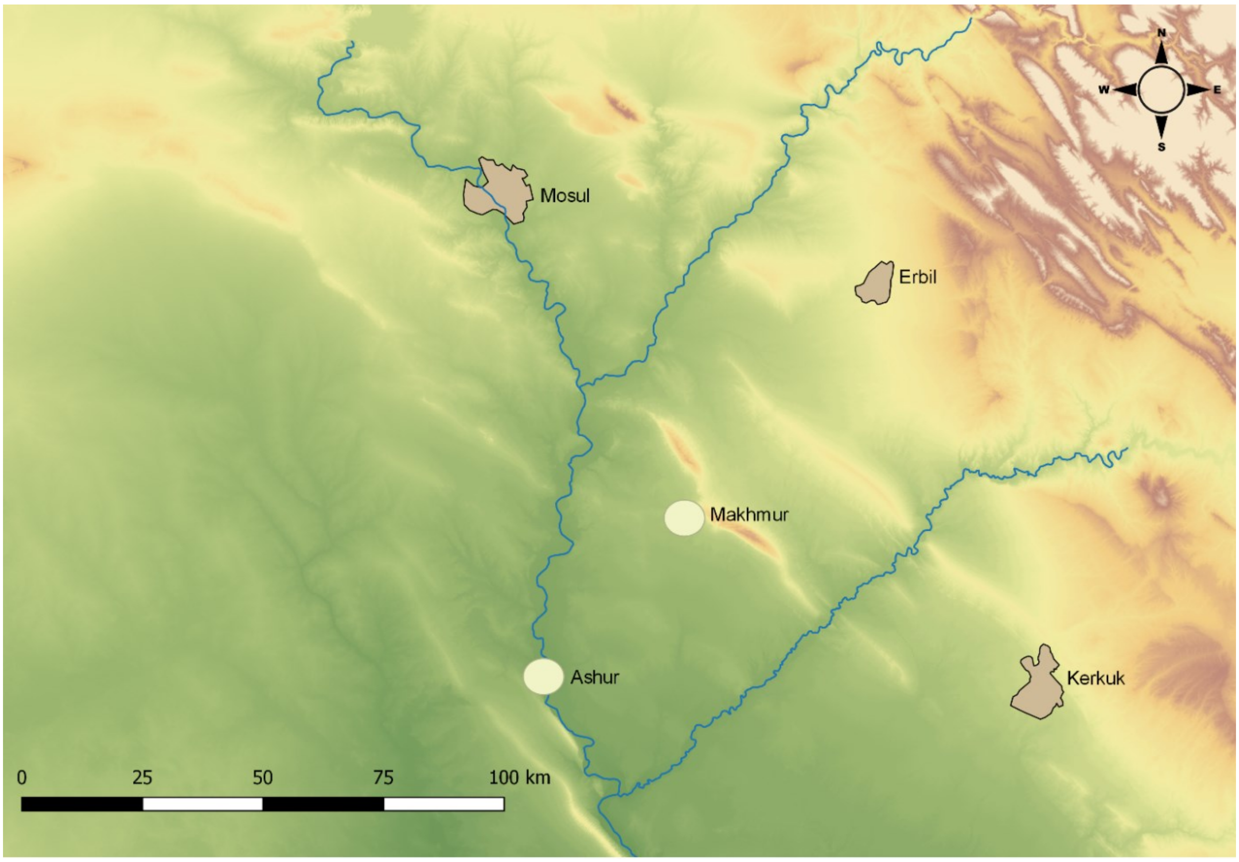

Fig. 1. Map of Northern Iraq showing the situation of Ashur (© Tobin Hartnell).

[1] The city of Hawija in western Kirkuk Province was the last urban stronghold of ISIL in Iraq.

Despite no reports of casualties at Ashur since late 2015, the logistics of conducting fieldwork there remain challenging. The project initially coordinated a police escort through Kirkuk Province (including Hawija District) but abandoned this approach after ISIL killed three Peshmerga on May 4th, 2019. There was an ISIL attack against Makhmur on May 10th, and a car bomb that killed four people in Kirkuk on May 26th. al-Baghdadi claimed ISIL's responsibility for an attack in Sri Lanka that same month. The Kirkuk police justifiably felt that they would become targets, if they helped the team travel through post-ISIL territory.

After contacting local and international security companies, it became clear that the cost of private security would consume all of the budget in just a few days of work. The team settled on a Sunni Arab police and military escort from Iraq's internal border at Makhmur which divides the Kurdish Region of Iraq (KRI) from the rest of the country. Thus, the project conducted a preliminary meet-and-greet with the local security and archaeology officials in Sherqat in July, and then a ground assessment of Ashur in late August, and aerial documentation of the site in early September. Post-processing continued until the 24th CHNT conference in November, and even for a few weeks afterwards.

The Barriers to Research at Post-ISIL Ashur

During the Coalition's liberation campaign, ISIL used various small, customized UAVs (colloquially drones) to drop munitions on coalition forces threatening their positions in Mosul and other strategic places, just as Coalition forces used their own UAVs for surveillance and to project power. Given this recent history of conflict, people living in post-ISIL territory still have trauma related to the use of UAVs in civilian contexts. For this reason, the civilian use of even small UAVs in Iraq is severely restricted and virtually the entire country is one large No Fly Zone (NFZ). For the documentation of Ashur, the project needed approval of the Ministry of Culture, the local office of SBAH, and the local security forces, in this case Sunni tribesmen led by the al-Jabouri tribes. Given that the security situation in post-ISIL territory remains fluid day-to-day, the project used a hardware solution (a specialized chip) to allow for flights at Ashur rather than go through a lengthy application process for a software fix with DJI.

Privacy in a Post-Conflict Environment

Even with local permits, SBAH continuously monitored the DJI Pro 4's daily operations. One of the primary concerns was to limit, as far as practically possible, any flight paths that went beyond the official boundaries of the World Heritage site. The territory north of the site is almost completely free of human occupation, as it consists of open land. The eastern boundary is formed by the natural course of the Tigris River. Thus, the main priority was to avoid flights over suburban districts that currently flank the western and southern sides of the site. Even though the actual fencing was stolen during the period of conflict, the line of the original BRC fence is still visible and formed the limits of the flight paths on the western side. The Wadi Zazi formed a natural boundary to the south.

Challenges of Flying in the Summer Heat

The timing of the project placed an additional burden on data collection. Logistical delays meant that the fieldwork was undertaken over the summer, when Ashur experienced highs between 39 and 42 °C (Accuweather, 2020). After meeting local stakeholders in July, the team originally aimed to complete two simultaneous assessments (ground and air) of the site in August. Unfortunately, mechanical problems with the drone limited the season to an in-depth ground-based assessment of the site. This assessment is notable because it was the first time that the team collected direct evidence for an Outer City of Ashur, in the form of ceramics exposed by informal excavations of the local brick factory over the last few decades. The existence of an outer city roughly doubles the previously recorded size of the site from c. 80 ha to c. 150 ha (Fig. 2). The third visit in early September conducted an intensive aerial survey that collected 11,914 photographs in 4K.

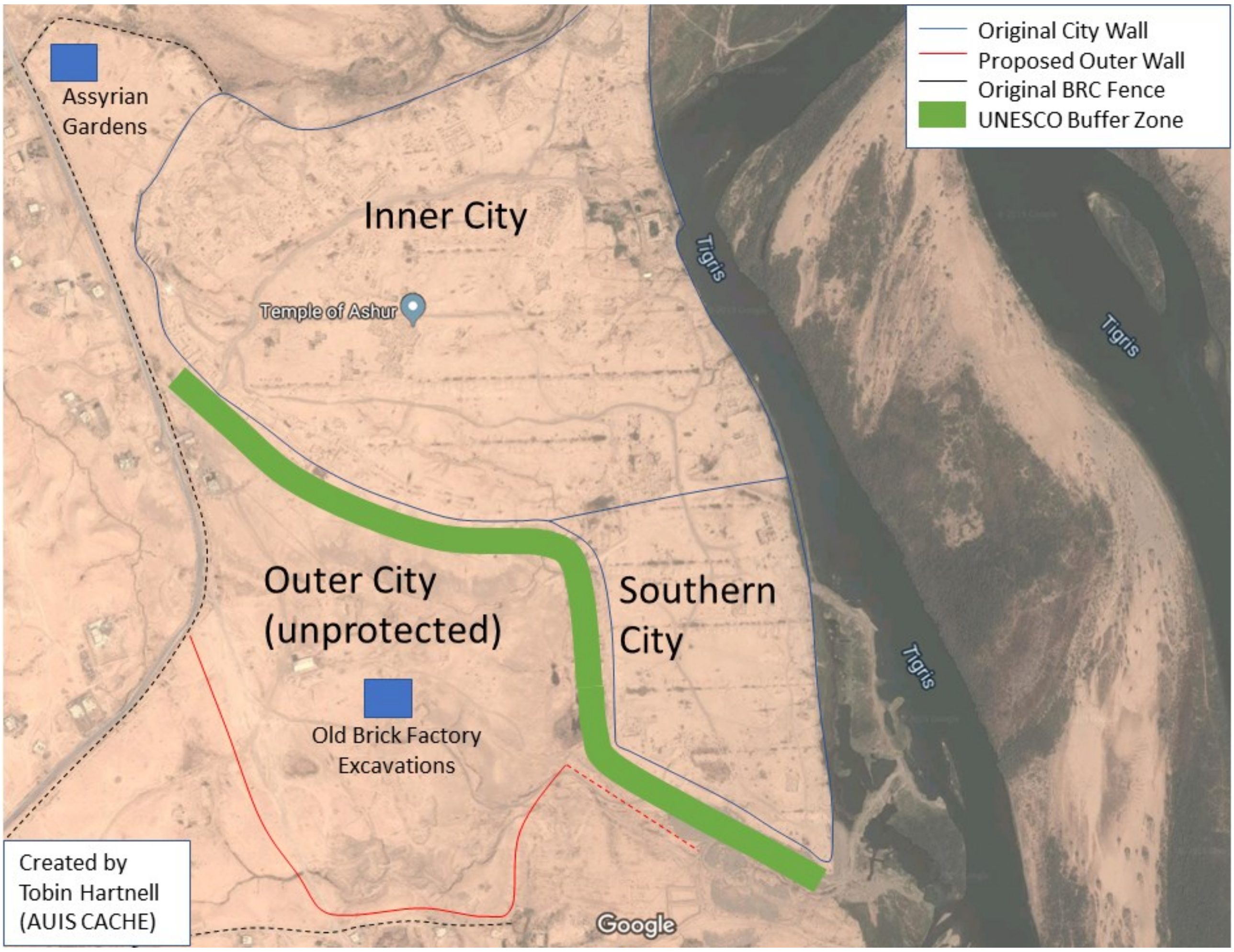

Fig. 2. Image of the City of Ashur with the Outer City (© Tobin Hartnell, not to scale).

Even with a mid-day break to avoid the worst of the heat, flying in early September in Iraq posed a number of environmental challenges to the fieldwork. The summer temperatures limited the sUAV's battery life and affected the operation of the iPhone and iPad mini that hosted the relevant app for planning and executing flights. Without these devices, the team would have no verification of what the drone was doing. At some point, the team lost the DJI 4 Pro in the northwestern section of the city for several minutes after the iPhone piloting the drone overheated and stopped working.

Fortunately, the sUAV initiated an auto landing sequence, and the team drove to relevant section of the buffer zone to retrieve it. From this point forward, an ice pack was a constant companion as the iPad mini used in subsequent flights would quickly overheat without it.

Infrastructural Challenges to Research in Post-Conflict Ashur

Even after keeping the iPad cool, there were two more problems – how to recharge batteries without reliable electricity and how to communicate with the drone between flights. ISIL sympathizers had effectively stripped the electric cables from all of the site, and destroyed the local SBAH offices. The SBAH residence that served as a temporary de facto office typically ran out of electricity by 11 am, which would effectively limit recharging time to the early morning. The August visit thus spent significant time and resources on improving the electricity supply to the SBAH residence, so that it could get a larger share of electricity from Iraq's national grid and also receive electricity from the Guard's residence where there was a diesel generator. For the September visit, the team also greatly increased the number of batteries from four to 10. Even then, the team would constantly swap batteries whilst being cautious about battery heat.

The final technical challenge was ensuring timely communication with the sUAV in a post-war environment that lacked significant infrastructure for accessing to the Internet. Wireless Internet was the only feasible option in the field, yet many of Iraq's 4G options are limited only to specific regions. At first, the team ran off personal hotspots from the smartphones of our SBAH partners. Eventually, the team decided on an Asiacell 4G (actually a slow 3.9 G) wireless connection that was stable but slow.

With limited access to Internet, the team had to pre-download every map, application, and online resource before going into the field every day. The limited Internet access also dictated the choice of flight software, as the Pix4D App required the drone operator to upload a significant load of data before every flight, which led to 15 to 20 minutes of downtime between each flight. The team's drone operator decided to install Drone Deploy which requires minimal data transfer between flights and downtime was limited to 30 seconds or less between flights. Given that this included the time required to change the batteries, the process was effectively seamless.

The overall goal of the aerial flights was to collect imagery 50x to 100x more detailed than images provided by commercial satellites. By limiting the forward overlap to 65 % and the side overlap to 60 %, the team could fly at 30 m altitude over the main mound and preserve a resolution of 1 cm/pixel, whilst it could fly at 60 m altitude over the Outer City and the Buffer Zone and preserve a resolution of 2 cm/pixel. This resolution compares very well to the superannuated Google Earth imagery available for Ashur (taken before the war against ISIL), as well as more recent commercial alternatives like Planet Labs (72 cm or 120 cm/pixel depending on the image quality; Fig. 3). High-resolution processing of the imagery resulted in several 3D composites of major landmarks of Ashur (Figures 4 and 5), though the computing time to render a complete 3D model at the highest possible resolution is expected to take two weeks of processing time.

Fig. 3. A visual comparison of Google Earth and low-altitude sUAV imagery of Ashur (© Tobin Hartnell and Adam Azad Tawfeeq).

Fig. 4. 3D Composite of the ziggurat, Temple of Ashur, and the destroyed on-site museum (© Adam Azad Tawfeeq).

Fig. 5. 3D composite of Ashur's Ziggurat (© Adam Azad Tawfeeq).

Creating an Artificial Intelligence Algorithm for the Ashur Project

The project's overall aim for using Artificial Intelligence (AI) was to increase efficiency and reduce the time it takes to process the large amount of data collected in the field. The team currently consists of just four people, and it had to handle over eleven thousand images. For this reason, the project trialed the use of AI as the primary means to classify the collected imagery. In terms of technology, the team's programmer used Tensorflow, a free and open-source software library developed by Google. The project later augmented Tensorflow with Keras, an open-source neural network library written in Python.

Though the project lacked significant IT resources at the office, the team included two cultural heritage experts proficient in Iraqi archaeology. The choice between supervised and unsupervised learning came down to the fact that the team could leverage its subject matter expertise (SME) to train the algorithm. Six students assisted the archaeologists in this process. A Supervised Learning Algorithm is a type of machine learning algorithm in which data or features are linked to pre-defined names or labels. Supervised learning is useful when the project has a large data set and a known output. For example, the project team pre-sorted thousands of images into categories such as mud-brick walls or excavation trenches. The input or feature is the data (the imagery) and the output matches the data to the label with varying degrees of confidence. The total cost of student labor for the AI project was less than $400 USD, whilst the other equipment and labor was donated.

Training the Model using Transfer Learning

Simplicity of implementation was a major factor in determining the method. The main reason behind using the Inception v3 model instead of custom building an AI model is that this model is designed with more expertise and has been trained on a huge library of data from *Image net* data set that the team cannot hope to match. In more technical language, Inception v3 is a pre-trained deep convolutional neural network model that is widely used for image classification (Szegedy et al., 2015;

Valigi, 2016; Google, 2019; Milton-Barker, 2019). The Inception v3 model has been trained on the *Image net* data set and shows great accuracy.

However, the project team still made some custom modifications to the Inception v3 model to better fit the project goals and then trained the last layer of the model on the field data through the transfer learning process. The learning rate is a user-defined parameter that modifies the model based on the estimated error each time the algorithm updates the model weights. In this case, the project team set the learning rate at 0.01. The Epoch is a reference to the number of iterations the model takes training data. In this case, the model trained itself in 500 steps. Through repeated optimization of the model, the project got the desired result.

Artificial Intelligence algorithms need a sufficiently large body of data for training (typically 500 images per category). The team set the testing percentage at 10 % of the total images available to the algorithm. Thus, for the roughly 500 images used in each trial categories, the team asked the algorithm to correctly identify 100 images. As all of the project's images came from a single source, the camera attached to the DJI Phantom Pro 4, and all images shared the same settings, there was little pre-processing required for the image dataset. The major obstacle was the presence of specialized metadata, which the algorithm could not handle. The team relied on XnConvert to batch process the imagery. XnConvert allows the operator to strip the metadata from the image during the conversion process. The preferred file format was JPEG. Image preparation took less than a day, once the correct technical solution was identified. Beyond this step, the project did not need to augment the data any further. Regarding the normalization process, the Inception v3 model uses the Batch Normalization Method, which was also used in this case.

Since most of the collected images contained multiple features and unrelated items, the project preferred to use a pre-trained model which is then trained on archaeological objects instead of building a custom model. Local trials used two sets of data, each containing around 500 images. As expected, the more data fed to the model, the better the classification result. An experimental trial used images of mudbrick walls and excavation trenches of various ages and states of preservation. The challenge was that a computer would have to correctly distinguish between trenches, other topographical features, and walls even after some archaeological features have been exposed to erosion for more than a century.

Preliminary Results of the Ashur Artificial Intelligence Project

The test consisted of 100 images chosen at random from those images not used to train the algorithm. Overall, the algorithm was successful. The model successfully identified features with an average of 87.7 % reliability, with 68 % of images having over 80 % reliability (Table 1). Of those images with a reliability rating of 80+% or greater, the algorithm correctly identified 100 % of the images. For those images with a reliability rating between 70 % and 79.99 %, the algorithm correctly identified 88.9 % of the images. The three false identifications from images with a reliability rating of 60–79.9 % seemingly derive from the nature of those images. In the first case (reliability 66 %), the image has a rectilinear feature (possibly a foundation) made of concrete. The algorithm seems to have incorrectly identified this concrete feature as a mudbrick wall. In the next two cases (78.57 % and 79.65 %), it appears that the algorithm identified old section walls as mudbrick walls (Fig. 6).

With more data and training, these false identifications can be minimized though probably never eliminated. The danger is that without subject matter experts holding significant local knowledge, the algorithm's false identifications may be accepted uncritically. For this reason, a subject matter expert should personally review those images with the lowest confidence rating to ensure the integrity of the result as well as those images that appear to be outliers based on the goals of the project.

Percentage of Reliability	Total Images by % of certainty	False Identifications
50–59.99 %	8	These results are too uncertain to be useful.
60–69.99 %	6	1
70–79.99 %	18	2
80–89.99 %	21	0
90–99.99 %	47	0

Table 1. Summary of the results of the Artificial Intelligence Algorithm.

Fig. 6. A sample of problematic images from the AI study (©Tobin Hartnell and Adam Azad Tawfeeq).

The Future of Artificial Intelligence at Ashur

Archaeological sites are complex and each image typically contains more than one feature. The current iteration of the Artificial Intelligence project has identified what subject matter experts considered the main feature in the image, yet it is possible to delineate specific features within the image before training the model. For example, a trained analyst would tell the computer which part of the image contained a wall and which part contained a road. By specifically focusing only on the feature itself, the algorithm will become more reliable even when identifying features that exhibit vegetation growth or suffered significant erosion. A second-generation Artificial Intelligence algorithm is currently under construction and should be ready for the 25th CHNT conference in Vienna.

On reflection, working in post-conflict Iraq requires flexibility to overcome the numerous environmental and social challenges facing the project. This year's work employed six students, two foreign archaeologists, three local archaeologists, and an IT professional for only $3500 USD. On top of that, transport, housing, and security for the fieldwork at Ashur was donated to the project free of charge. With significant planning and the right support, important fieldwork on a limited budget is possible even in a post-conflict environment. For this reason, the team would like to finish this article by thanking all the people who contributed to making the preliminary work at Ashur a success.[2]

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