Resurrection of the Mongolian Steppe Empire: Data Recording, Reconstruction and Automated Interpretation

Application and development of deep learning methods in the context of the Uighur capital of the 9th century

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Keywords: 3d reconstruction, photogrammetry, videogrammetry, deep learning, Mongolian empire, DeepStructure

Motivation and Introduction

In September 2018, 52 km^2 were recorded in the Mongolian steppe (see Fig. 1) in just five days using commercially available multicopters presented by Block in (2018).

Fig. 1. 1200 years old remains of the Uighur capital of the 9th century. If the light comes strongly from the side and the observer takes the correct position, otherwise hardly perceptible structures become visible.

In 1999, the Mongolian-German joint research projects started with surveys and excavations in Karakorum and in 2007 in Karabalghasun (Franken et. al 2017). Detailed plans of the ancient remains on the surface are a crucial prerequisite for further research and understanding of the steppe cities. The steppe provides almost perfect conditions for remote sensing techniques due to its sparse vegetation. Since the research on urban sites in the steppe is more and more interested in questions after the urban hinterland, urban sprawl and wide-ranging settlement patterns (Honeychurch & Amartuvshin 2007, Waugh 2010), detailed mappings of huge areas are necessary. The challenge arose to survey large areas in a short period of time with affordable equipment and to process the gathered data for scientific analysis.

Today's technical possibilities lead to an ever increasing amount of data in ever shorter time. However, the data must also be analysed and evaluated. For this reason, the semi-automated tool DeepStructure was developed to detect, visualize and classify existing city contours and settlement remains.

Data acquisition and 3D reconstruction

An accurate preliminary planning enabled the systematic parallel flight with two multicopters of the type Phantom 4 Pro at an altitude of $100\ m$ with a flying area of. 526 m x 526 m Pix4DCapture was used for the flight planning and the web service DroneDeploy for the processing. For the 3D-reconstruction of the

monastery Erdeene Zuu a photo based survey was carried out. This enables automatic georeferencing with the help of the geotags present in the images. Subsequently, video-based surveys were carried out and reconstructed videogrammetrically (Block 2018). Natural markers, which are available in both models, are used for georeferencing.

In the elevation models of the steppe structures could be made visible, which are not easily perceptible from the ground and from the aerial photographs (see Fig. 2).

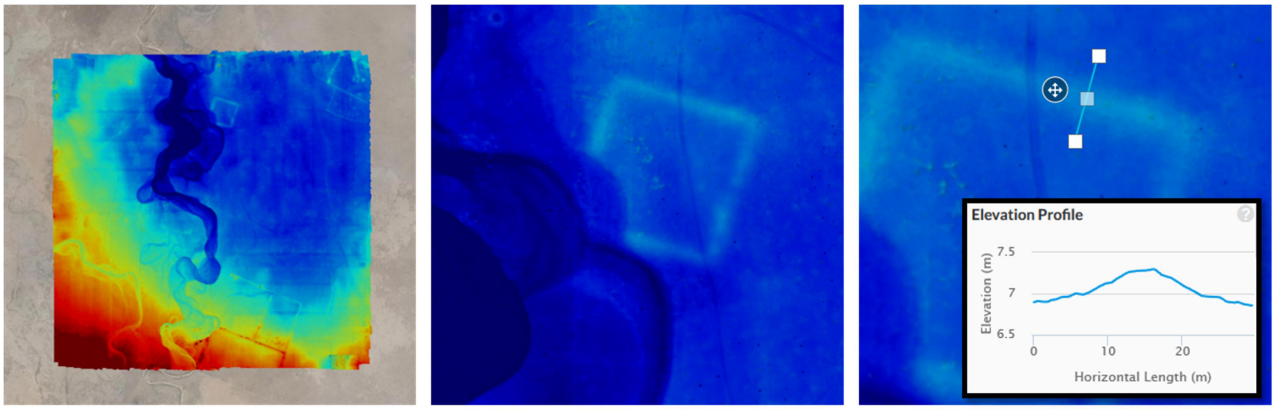

Fig. 2. Left: For a patch with the dimensions of 1.1 km^2 four flights with a net time of 30 minutes were needed, whereby two flights took place parallel. The results can be seen in the elevation model. Middle: A significant structure can be seen here in the northern area. Right: A profile line with a length of 30 m shows that the existing structure on this length makes up a height difference of only 30 cm. This makes it barely perceptible on the ground.

Semi-automatic data processing

With a semi-automated approach, a processing pipeline for geodata is presented. With the focus on segmentation for the identification of archaeological structures, the elevation data of the 52 square kilometers are used. The result of this investigation should be an automatically generated city map from digital elevation data. There are a number of visualisation techniques for digital elevation models (hillshading, topological openness, sky-view-factor). Each of the techniques has its own characteristics, but also limits. In order to use these techniques properly, the results have to compared, to know which landscape suits which technique. Making the images more understandable, visualisation from remote sensing and methods from computer science were used together to enhance the visibility of certain landscape properties.

Module DeepStructure in ArchaeoAnalytics

A tool named DeepStructure was developed and integrated in ArchaeoAnalytics that helps user to find interesting areas in large data sets quicker and make them more visible. A pipeline was created that combines the strengths of visualisation techniques and image processing. The automation of individual phases simplifies the work and enables a faster processing of data, e.g. interpolation point clouds or georeferencing batch of images. The biggest challenge in analysing the results of the monogolics campaign was the weak remains of the city, which are still visible in the steppe soil. Image preprocessing steps (morpholigical operations, histogram stretching, local constrast segmentation, watershield) and adjusting the right edge filter (holisticaly nested edge detection) were relevant to find these hidden structures. In addition to classic edge filters, methods from machine learning (hair cascades in opencv, yolo deep learning) were also used. Nevertheless, the results show that it still needs the help of a human to adjust the appropriate parameters to recognise the human made structures. The amount of human input depends on

the concrete situation. A benchmark test with ground truth data ist still in progress, therefore at this time no value of accuracy can be given.

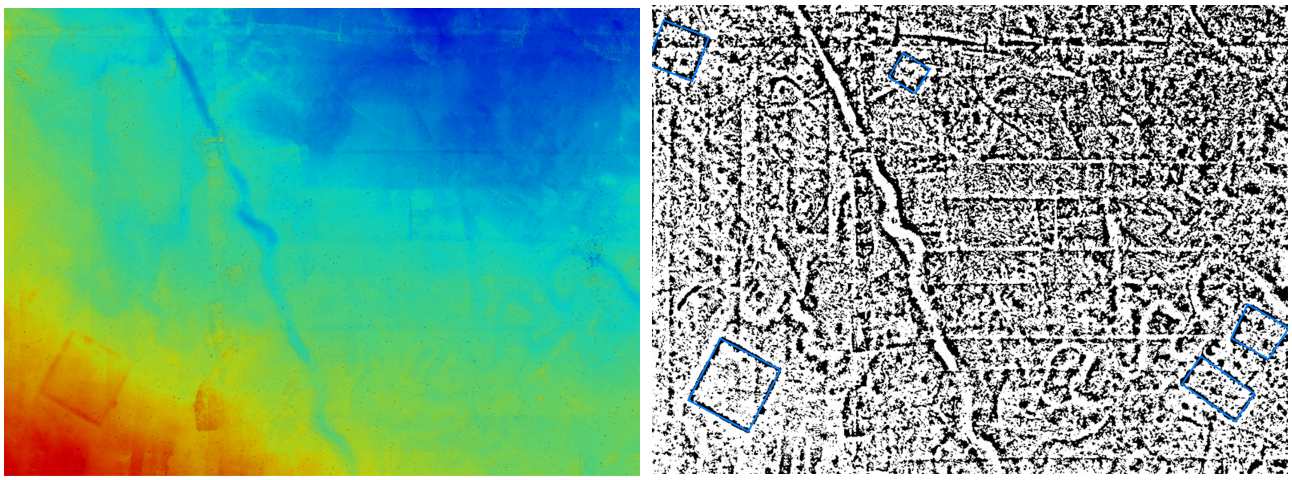

Fig. 2. Left: An elevation model without any image processing are some structures slightly visible. Right: An example of the result a combination of image processing methods (local contrast segmentation, morphological dilation and erosion) and remote sensing visualisation (topographical openness). Structures are much more visible and shapes are discovered which are almost not perceptible on the raw elevation model on the left.

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