Computational approaches to archaeological site detection and monitoring

Saturday 29th February 2020

Talks and abstracts

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Extracting archaeologically-relevant information from imagery in manual and (semi-)automated ways

Geert Verhoeven (Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology)

Today, there is a broad consensus among archaeologists that remote sensing encompasses a range of useful observational techniques for discovering and registering archaeological traces and landscape patterning. Since remote sensing is a generic name given to all methods that use propagated signals to observe the Earth’s surface from above, many different remote sensing systems exist, and they can all be characterised as imaging versus non-imaging, passive versus active, optical versus non-optical, and airborne versus spaceborne. Given the long history of aerial photography in archaeology, this talk will target only products from passive airborne optical imaging approaches. More in particular, the presentation will kick off by considering the multi-dimensional nature of images and illustrate how both the geometrical and spectral image dimensions can yield new data products that might enhance (or even enable) the manual archaeological interpretation of the scene depicted in the image. At this point, the presentation will bridge from this rather traditional interpretative mapping approach to the desire for more automation using pattern recognition techniques. Building upon the principles of the first part, the underlying rationale of pattern recognition and its reliance on image features will be explained. The talk will state the difference between (and strike a blow for) hand-crafted image features used in traditional pattern recognition approaches versus those that are concocted during deep learning within the ubiquitous artificial neural architectures. A handful of epistemological and methodological considerations concerning deep archaeological remote sensing learning will top of this talk.

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Potentials of earth observation virtual constellations and big data: moving beyond current archaeological prospection practices

Athos Agapiou (Cyprus University of Technology)

Nowadays, a variety of satellite images have become accessible to researchers. Fleets of nanosatellites can collect images up to 2 million km² per day, while satellite optical videos have also been recently introduced. Moreover, National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) provide a unique opportunity for researchers to work with a significant amount of open access and freely distributed earth observation imageries by exploiting big data cloud platforms and services.

These changes are expected to impact the up-to-now traditional methodologies applied in the scientific field of archaeological prospection, thus moving beyond data complexities and current practices. However, despite the increasing availability of sensors, earth observation related research will be still restricted by the mismatch observed between the individual sensors’ characteristics and operational wavelength range.

This communication raises some thoughts linked towards the synergistic and coordinate use of earth observation sensors, developed in the framework of the virtual space-based constellations, as proposed by the Committee on Earth Observation Satellites (CEOS). Earth observation virtual constellations can increase data availability and provide further information for future archaeological prospection research. This will allow us to fully exploit the capacity of existing sensors and understand their potential synergies, expanding thus the scope of individual datasets, aiming to meet the needs and challenges of archaeological research. This short communication will showcase preliminary examples from this effort.
Seeing the patterns that persist in time – using multitemporal classification of multispectral images for archaeological prospection

Bjoern Menze (Technical University of Munich), and Jason Ur (Harvard University)

The analysis of spatio-temporal surface patterns is central to many applications in satellite remote sensing. In land-use monitoring, for example, algorithms deal with the detection of specific changes of the land cover, or the accurate quantification of urban growth. In archaeological prospection tasks, however, we have to deal with the opposite case: we are interested in mapping surface patterns that remain static over time and want to remove the effect of annual and interannual short-term variation from changes in ground cover. In [Menze Ur, PNAS 2012] and [Menze Ur, JSTARS 2014] we have presented a multitemporal classification strategy for mapping characteristic soil difference in Near Easter landscapes that is only requires limited ground control and that can be used to inter- and extrapolate evidence from ground survey. It addresses the task of removing temporal variation by making use of all multispectral images that are available for a region of interest, and uses machine learning techniques to process and fuse them in an automated fashion. In this talk I will demonstrate the use of SENTINEL-2 images, instead of the earlier ASTER data, and discuss new initial results obtained for the Erbil plain, a landscape in northern Iraq with complex landscape patterns that has tight ground control available from the ongoing EPAS archaeological survey.

3D Shape, Visual Perception, Recognizing ‘Archaeology’, and creating Learning Sets for Archaeological Lidar Studies

Rachel Opitz (University of Glasgow), with Dave Cowley

This paper explores the links and differences between how we learn to recognize archaeological topographic features through our interactions with physical and digital landscapes, and discusses implications for the use of AI in archaeological surveys based on the identification of features in lidar-derived terrain models (LDTMs). The development of well-designed learning sets in particular is strongly conditioned by our approaches identifying archaeological entities. Consequently, the process of establishing learning sets is prompting renewed discussion about the fundamental basis for the visual identification of topographic features, returning us to questions including: What morphological features and properties in an archaeological entity are most important to its recognition? Will ML/CV approaches encourage or discourage the identification of exceptional or unusual features? Is landscape context a key part of the recognition process which should be incorporated into learning sets? Are differences between measured shape and perceived shape important in this context?
Uncovering the archaeological landscape of the Veluwe, central Netherlands, through remote sensing, deep learning and citizen science

Karsten Lambers (University of Leiden), with Quentin Bourgeois, Wouter Verschoof-van der Vaart, Eva Kaptijn and Alex Brandsen

This talk will provide an update on ongoing archaeological research on the Veluwe, one of the few densely forested areas in the Netherlands. While many archaeological traces are well preserved under the forest cover, they are also well hidden. In spite of decades of archaeological fieldwork by Leiden University and others, our knowledge of the rich archaeological heritage of the Veluwe is still sketchy.

Two recently launched, interconnected research projects are currently expanding our knowledge considerably. Both approach the Veluwe from a regional perspective. In the first project, WODAN (Workflow for Object Detection of Archaeology in the Netherlands) we are developing a multi-class detector of archaeological objects in LiDAR data, the core of which is a Faster R-CNN (region-based convolutional neural network). This project has more than tripled the amount of known prehistoric burial mounds in the region, and has also allowed substantial progress in the study of Celtic fields and charcoal kilns. In a second project, Heritage Quest hundreds of citizen researchers are mapping the same three object categories in LiDAR data, and some of them are helping us to verify them in the field, which again expands the number of known objects considerably.

Both projects inform each other through the mutual proposal and cross-validation of potential archaeological objects. They also generate data that allow us to assess and compare the performance of experts, volunteers, and neural networks in the detection and mapping of archaeological objects.

Streamlining and automating: developing approaches to archaeological survey in a national heritage agency

Dave Cowley (Historic Environment Scotland), with Lukasz Banaszek, George Geddes, Iris Kramer and Rachel Opitz

Many of the processes that have underpinned archaeological survey are manual, reflecting workflows and approaches which developed during the ‘analogue’ era. The proliferation of digital data and computation present a series of challenges and opportunities to archaeological surveyors in a born-digital world. This paper presents preliminary outcomes from two strands of ongoing research and development at Historic Environment Scotland. Firstly, we will discuss attempts to formalise, automate and streamline processes of archaeological survey that have previously been based on profoundly ‘manual’ approaches. Secondly, we explore opportunities in automated object detection which aim to expedite the identification of the anthropogenic across very large areas (>100km²), exposing the both manual (human interpreter) and automated (CNN) detection and classification routines. In each area, we are attempting to build adaptable methods for large-area survey that draw heavily on computational approaches and make best use of knowledge and experience built through field engagement.
Protecting the heritage of the Middle East and North Africa using remote sensing

Louise Rayne (University of Leicester), with David Mattingly, Bob Bewley, Andrew Wilson and Graham Philip

The Endangered Archaeology in the Middle East and North Africa (EAMENA) project is using remote sensing to document archaeological sites and the threats posed to them in an online database. We discuss trends of damage and threats which we have identified and our strategies for risk monitoring and mitigation. While damage to archaeological sites due to conflict is often high profile, significant damage is caused by the impacts of modern land use activities. We discuss selected case studies from our region of interest, for example the ancient oases of Al-Jufra in Libya which have been damaged by agricultural expansion and sites around Aswan in Egypt.

Multispectral data allows changes to sites to be monitored and higher-resolution imagery is used for digitising archaeology. Over 250,000 sites have been documented in detail using these data and this process is ongoing. We use open-source software and data so that the EAMENA database and methodology is as widely available as possible to cultural heritage professionals in the MENA region. Strategies for minimising risk to archaeological sites include automated change detection and training archaeologists in remote sensing methods.

Computational landscape archaeology in South Asia: integrated approaches for the remote detection of archaeological features

Arnau Garcia-Molsosa (Catalan Institute of Classical Archaeology) and Francesc C. Conesa (University of Cambridge), with Hector A. Orengo, Adam Green, Agustin Lobo and Cameron A. Petrie

This paper will summarise the research workflows that have been carried out by our research team at the McDonald Institute for Archaeological Research and the Catalan Institute of Classical Archaeology. Our investigations have focus on the development of large scale, multi-source and multi-temporal integrated approaches for the detection of archaeological and paleoenvironmental features in the north-western regions of South Asia. The study areas were core to the development of the riverine Bronze Age Indus Valley Civilisation (ca 3300-1900 BC), and many Indus sites, some of them large urban centres, are closely located to major river systems or fossilised paleochannels. The regions encompass today a range of distinct ecological settings, such as the fertile monsoonal alluvial plains of Punjab and Haryana and the hyper-arid lands of the Cholistan Desert.

Our research strategy has combined the semi-automated extraction of features from historical topographical maps, specially the former Survey of India map series (1905-1944), with a research workflow based on the implementation of new algorithms in multi-petabyte cloud computing environments such as Google Earth Engine, providing access to global, freely available imagery (such as the EU Copernicus Programme) and facilitating the integration of third-party products such as TanDEM-X elevation models. Data mining and analysis have been carried out to: 1) identify Indus sites and delineate palaeohydrological networks in alluvial plains, using multispectral-based analysis and topographic reconstructions; and to 2) accurately and automatically detect mound-like features in desert lands using a multi-sensor, multi-temporal machine-learning approach.
**Untangling uncertainty: building robust archaeological datasets through geophysical methods**

Philippe De Smedt (Ghent University)

Over the past two decades, geophysical methods have gained a widespread acceptance within the archaeological community. Particularly with the increasing capacity to survey larger areas more efficiently and at ever finer sampling resolutions, the relevance of geophysical data for archaeological research will undoubtedly only expand over time.

Geophysical data now often incorporate subsurface discrimination potential at the decimeter scale, and – for specific applications – in three dimensions. Vehicle-mounted arrays enable collecting such data over several hectares per day. These impressive metrics are unfortunately accompanied by an increased burden on data processing and interpretation. While the former is circumvented partly by increased computational power, the latter lingers behind. Although automation procedures, such as computer aided object identification, are becoming part of the interpretive process of archaeo-geophysical datasets, they remain subject to criticism. This stems from the inherent uncertainty that defines geophysical data, and is exacerbated by the complexity of the archaeological record.

In this presentation, an overview is given of what defines this uncertain nature of geophysical data, and how this affects reliability of archaeo-geophysical datasets. Looking to the future, it is proposed how interpretive frameworks can be constructed to support more efficient and reliable translation of geophysical data to archaeological knowledge.

**Predict, detect, evaluate, repeat. Towards developing a shared knowledge system for (automated) detection of archaeological remains**

Philip Verhagen (Vrije Universiteit Amsterdam)

Over the past decade, archaeological predictive modelling of site locations has more and more given way to direct observation of archaeological traces either from the air, using geophysical prospection, or by subsurface interventions. While the direct use of predictive modelling for risk assessment in archaeological heritage management has thus gradually decreased, prediction is and should still be part of the workflow for detecting and evaluating archaeological remains. In fact, it is only becoming more urgent, since the capabilities of modern detection techniques highly depend on specific characteristics of the archaeological remains considered and their manifestation on the ground or below the surface. Automated detection methods deserve particular scrutiny in this respect.

In this paper, I will propose a workflow based on ontological reasoning to better understand the relationship between prediction, detection and evaluation, and I will argue the importance of setting up a shared knowledge system for this.