S20 Computer vision vs human perception in remote sensing image analysis: Time to move on

Arianna Traviglia, Karsten Lambers

The (slow) emergence of semi-automated or supervised detection techniques to identify anthropogenic features over remote sensing imagery have received mixed reception in the past decade, with critics stressing the superiority of human vision and the irreplaceability of human judgement in recognising archaeological features, and supporters working toward the development of (semi)automated computer vision methodologies to streamline the screening of aerial/satellite imagery. This limited development has been due to a number of reasons, of which probably the most relevant are, on one side, an uneasiness of archaeologists in handing over—even partially—the interpretation process to machine-based judgment and, on the other, the fact that archaeological features can assume a near-unlimited assortment of shapes, sizes and spectral properties, which makes particularly challenging their auto-extraction. Thus, while (semi)automated and supervised procedures for feature extraction and processing are flourishing in a variety of fields, allowing for large swathes of landscapes to be simultaneously investigated, their application to archaeological and, more generally, cultural landscapes is still in its infancy.

A number of approaches in Feature extraction, Pattern Recognition, Pattern Matching, to name a few, now offer the opportunity to adopt (semi)automated feature detection and processing methods to identify potential archaeological features. These approaches can overcome the previous limitations of spectral and object-based methods and enable recognition of landscape patterns/features produced by a variety of diverse natural or artificial elements.

This session invites presentations showcasing computer-vision methods that are being used or developed to automatically identify landscape features and/or patterns on remote sensing imagery and it is—purposely—open to research employing broadly defined 'remote sensing data'. The session also welcomes controversial papers examining more broadly the subject from a theoretical point of view and addressing the topic from an antagonist angle.

S20-01 Why, when and how? Context and computer vision in archaeological prospection and interpretation

Dave Cowley

As the session abstract identifies, the debate over applications of semi-automated or supervised feature extraction techniques in archaeology has tended to be polarised between believers and doubters. In large part the polarisation of discussion probably stems from a lack of explicitness about how archaeological feature identification is undertaken and how the processes, whether ‘automated' or ‘human', of identifying patterns, shapes and features interrelate with archaeological interpretation. Furthermore, the varying contexts of these processes in multi-scaled archaeological prospection have not necessarily been defined as fully as they might. Such ambiguity is unhelpful to exploration of the potential of new techniques, and the interfaces between traditional archaeological skills/knowledge and emergent tools. It also makes definition of common purpose difficult. This paper will explore these issues, looking to address the reasons why the application of computer vision to archaeological prospection is vital, but also examining the workflows and outcomes of different approaches and processes, both manual and automated. These are important steps in addressing some key questions, including: how can we create clarity about why and when automated approaches are desirable?; what are the roles of (traditional/manual) archaeological experience and skills in designing algorithms?; and how can automated/manual approaches be used iteratively to improve archaeological detection?

S20-02 Computer vision applied to historical air photos: The registration and object detection challenge

Sebastian Zambanini, Fabian Hollaus, Robert Sablatnig

This paper addresses the problem of automatically analyzing aerial photos taken during World War II air strikes. The goal of this work is to locate unexploded ordnances (UXOs) for risk assessments, enabled by the registration of the historical air photos to modern-day satellite images and the detection of military objects (e.g. bomb craters or trenches). The work is part of the DeVisOR project which aims at supporting the tedious task of creating UXO surveys in a semi-automatic manner by means of powerful image analysis methods and interactive visualization techniques.

In this paper we focus on the image analysis part and present the specific challenges that arise when working with this kind of data. For registration, the strong image changes caused by time spans of around 70 years hinder the reliable identification of correspondences between the old and new images, especially in non-urban areas. In combination with the generally low image quality of the old aerial photos and the appearance variations caused by illumination changes, a straightforward solution based on standard algorithms using key point matching and sample-based transformation estimation does not exist. The same problem appears for the detection task, which is additionally impeded by the absence of large amounts of training data. Consequently, innovative solutions are required that are tailored to the specific conditions of the problem.

S20-03 Semi-automatic detection of charcoal kilns from airborne laser scanning data

Øivind Due Trier, Arnt-Børre Salberg, Lars Holger Pilø

This paper presents new methods for the semi-automatic detection of charcoal kilns from airborne laser scanning (ALS) data.

The 17th century saw the establishment of a number of iron works in Norway, based on the need of the Danish king for iron for ships, armaments and other military purposes. The iron works at Lesja, Oppland County, was established 1660. Surveys in connection with cultural heritage management work have pointed to the presence of large numbers of charcoal kilns in the area surrounding the Lesja Iron Works. It was not known, however, what the total number of preserved kilns was, if they showed sign of reuse, and how they were distributed throughout the landscape.

In 2013 the entire forested valley in Lesja was mapped by ALS with five first returns per m2. The initial visual interpretation of the ALS data, focusing on the central area, yielded about one thousand possible charcoal kilns. All were round, with a diameter between 10 and 20 m. However, the edge of the kilns had a varied topographical expression. Some kilns had a ditch surrounding them, some had pits, and some had a combination of the two. In addition some kilns had a low mound inside the ditch/pits or even pits inside the circumference.

In order to conduct a complete mapping, covering the different shapes of charcoal kiln, several detection methods are used: (1) mound detection, (2) pit detection, (3) circular ditch detection, and (4) partial ditch detection. Although many individual charcoal kilns are missed by the automatic detection methods, many are also detected, leading the archaeologist to look for additional charcoal kilns nearby. In conclusion, the automatic detection methods are improving the quality of visual interpretation of the ALS data, and make the field work more efficient.

S20-04 Two methods for semi-automated feature extraction from Lidar‒derived DEM designed for cairn‒fields and burial mounds

Benjamin Stular

We are in agreement with the session call that among others a reason hindering more efficient emergence of semi-automated or supervised detection techniques to identify anthropogenic features on remote-sensing data are critics stressing the irreplaceability of human judgement in recognising archaeological features. In the case of the Lidar-derived data, it seems, the prevailing reason is the fact that archaeological features come in a near-unlimited assortment of shapes and sizes, though. Thus, the successful efforts so far have been focused on a limited number of homogenous feature types that appear in great quantity, i.e. roads, open mining shafts or cairn-fields. We are presenting two methods developed for semi-automated detection of individual cairns within a cairn-field. The first method is based on the standard-deviation-of-elevation based local relief and subsequent classification of 2D shapes. The second method is based on peak finding algorithm. Both methods are implemented in existing free GIS software packages. The pipeline for the two methods will be presented. The results will be showcased and discussed on two different case studies aiming at providing not just an "ideal" condition but also a very demanding one.

S20-05 Using eCognition to improve feature recognition

Iris Caroline Kramer

While automated feature recognition is still in its infancy in archaeology, within the geosciences recent developments have allowed its application to much more irregular typology, such as the supervised classification of landslides. This success is largely due to the geographical object-based image analysis software TRIMBLE eCognition. In archaeology, this programme has been applied to some extent, yet new additions to the array of available methods require a re-evaluation of its potential for feature recognition. For instance, the ability to integrate LiDAR data and aerial photography has long been desired within archaeology. Additionally, the ability to transfer rulesets for the detection of common features can facilitate data and knowledge-sharing amongst researchers. The case study will present three different automated detection methods; using the well-known eCognition ruleset generation based on cognitive reasoning; self-learning algorithms; and adaptive template matching. These techniques are applied to round barrow detection in the Avebury region in southern England, specifically distinguishing between the known variations of barrow, bank and ditch. Each method is assessed according to its usability for large regions and its potential for detecting variable features and complex shapes. The algorithms are intended to prioritise cognitive aspects of human vision such as elevation, size, shape and texture, using the LiDAR data and aerial photography. It is also stressed that ruleset exchange for generally known features and processes is highly important for mapping large areas across borders and is intrinsically supported by eCognition.

S20-06 Automated detection of stone‒walled ruins using based on support vector machine and histogram of oriented gradients

Amandine Robin, Karim Sadr

Aerial or satellite imagery allow archaeological surveys of large areas for a fraction of the time and cost of ground surveys. Nevertheless, the task of examining reams of air photographs or zooming into details on Google Earth is also a time consuming exercise. Therefore a desirable objective is to find a way of automating the detection of archaeological sites on remotely sensed imagery.

This new method proposes an autonomous approach to detect ruins, based on Histograms of Oriented Gradients for feature extraction and on a Support Vector Machine in order to

classify the extracted features into a ruin vs non-ruin class. The support vector machine uses a training set to learn to distinguish the ruins from the rest, and is then applied to a wide area without any a priori knowledge to detect the ruins. The approach is validated over the Suikerbostrand area in South Africa, to identify and classify pre- colonial stone–walled structures in an 8000 km2 study area. Over 7000 structures have been identified by a team of research assistants and are used as ground truth. The main challenges specific to this context are that the structures we seek to detect are very subtle and made from locally available material, shapes are diverse and tend to be occluded by other features such as vegetation. Thus, ruins are difficult to differentiate from natural features.
The performances of the method are analyzed depending on the set used for training, and the use of satellite images (LANDSAT, from Google Earth) vs LIDAR images is discussed. In both cases, the results demonstrate the relevance of this approach with a very good level of accuracy (more than 85%) and a good control of the false detections.

S20-07 Experiments in the automatic detection of archaeological features in remotely sensed data from Great Plains USA villages
Kenneth L Kvamme
Numerous prehistoric villages associated with native farming tribes of the Great Plains, USA, have been investigated through ground-based geophysics and aerial remote sensing, including Lidar. These villages vary from 1-20 ha and contain a number of common features including houses of various forms and sizes, ceremonial structures, plazas, and fortification ditches linked with bastions. Within houses, hearths and food storage pits represent features of great interest, important for dating and gaining samples of artifacts, faunal, and botanical remains. Large features are visible to varying degrees in Lidar, normal light or thermal infrared aerial imagery, or in site-wide electrical resistivity data, while hearths and storage pits are detectable through magnetometry. This paper explores whether such features be extracted and automatically classified through computer operations alone. The GIS toolbox offers unrealized potential for the identification of archaeological features in such data, simply because few investigators have attempted to do so. The focus here is on how relatively common GIS tools can be employed for the identification of specific archaeological feature types that exist in Great Plains villages using remotely sensed data. Pre-processing employs image manipulation tools (low and high–pass filters) to simplify noisy data and remove local geological or topographical trends, while Fourier methods isolate and remove periodicities (e.g., plow marks that obscure the archaeological signal). Reclassification tools permit definitions of anomalous objects or potential features. Shape indices give their approximate shapes, their sizes may be calculated, and proximities between them may be determined (though "distance" modules); the last permits realizations of context. Custom filters may be designed to recognize complex shapes through pattern matching approaches. Using these tools, pathways are developed for each of the previously cited feature types of archaeological interest. Collectively, they offer a diverse array of decision making mechanisms for the identification and classification of complex archaeological features.

S20-08 Down to the last pixel: Multiband use for direct detection of Caribbean indigenous archaeology
Till Frieder Sonnemann, William Megarry, Eduardo Herrera Malatesta, Douglas Comer
The use of satellite imagery has been so far very limited in detecting pre-colonial settlement archaeology in the Caribbean. Most superficial evidence of building structures has long perished. What remains are slight topographic modifications, house platforms and small mounds predominantly made of midden and soil that also include ceramics and lithic assemblages. The altered topography together with the surface scatter may however serve as

quantifiable indicators to represent an archaeological site. With the precise location of known sample sites, and the information of areas with no archaeological evidence, the authors use a variety of available data sets, a combination of multispectral bands (Worldview-2, Aster, LandSAT) and SAR (UAVSAR L-band, TanDEM-X) to feed a direct detection algorithm developed at CSRM and Johns Hopkins University. The pre-processed very diverse data has to be exactly matching in resolution and location, feeding a semi-automatic process to cross-correlate the datasets that requires supercomputing. Resulting maps present quantifiable statistical results of areas with similar pixel value combinations, with high probability of archaeological evidence. Three trial areas with sufficient diverse image coverage were chosen on the island of Hispaniola, representing different types of environments and crossing country boundaries, situated in Dominican Republic and Haiti. All areas have a number of sites identified through non-systematic surveys. A fourth region where a systematic survey was performed over a smaller area is used as a reference to validate the method.