Past, present and future of Remote Sensing in Archaeology:
an explicitly European perspective

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Abstract

All non-invasive approaches to viewing the buried and nominally ‘invisible’ evidence of the past should be included within the definition of Remote Sensing for archaeology. These approaches include space- and airborne sensor platforms, including traditional air photographic sensors as well as technology-based multi-spectral or hyperspectral scanners, as well as ground based geophysics, under-water remote sensing and other non-invasive techniques such as surface collection. In essence any method that facilitates observation of the buried evidence without impacting the surviving stratigraphy is encompassed within the remit of remote sensing. The last ten years have seen many innovations in remote sensing, the most significant advances having been achieved in the field of satellite imagery, LiDAR, UAV and geophysical prospection. Remote sensing has grown progressively from an ‘aseptic tool’ aimed at documentation into an original methodology, highly effective for the identification of archaeological sites and landscapes. It is currently – in its most advanced applications – the key to overcoming an out-dated approach to archaeological research and conservation focused on individual sites and then on finds.
PAST, PRESENT AND FUTURE OF REMOTE SENSING
An explicitly Archaeological and European Perspective

Introduction
WESSEX FROM THE AIR

By
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and
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F.S.A., F.G.S.

with contributions by
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OXFORD
AT THE CLARENDON PRESS
1928
Remote Sensing is now commonly used to describe:

THE SCIENCE OF IDENTIFYING, OBSERVING, INTERPRETING AND MEASURING OBJECTS OR SURFACES WITHOUT COMING INTO DIRECT CONTACT WITH THEM.

The European archaeological community has taken at least two different approaches to the definition of Remote Sensing:

Some archaeologists define it as the technique of obtaining information about objects through the analysis of data collected by sensors (cameras, scanners, imaging radar systems etc) that are not in physical contact with the objects under investigation, using spaceborne and airborne instruments.
Some other archaeologists define remote sensing as: any non invasive approaches to viewing the buried and nominally ‘invisible’ evidence of past activity should be included within remote sensing for archaeology. These approaches include space and air borne sensor platforms - these might be traditional air photographic sensors as well as technology based multi-spectral or hyper spectral scanners, as well as ground based geophysics, under sea remote sensing and other non-invasive techniques such as surface collection; in essence any method that facilitates observation of the buried evidence without impacting the surviving stratigraphy is encompassed within the remit of remote sensing.

however...

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<td><strong>What happened in the archaeological scientific community?</strong></td>
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For a long period the technologies involved in Remote Sensing were considered to be ‘leading edge’ and it was fairly unusual for archaeologists to access them.

It must be acknowledged, too, that the relationship between archaeologists and technology has not always been free of pain and frustration.

Despite this, in the last thirty years technology has become more and more common in the archaeological laboratory and also in the field.

<table>
<thead>
<tr>
<th>Introduction</th>
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Introduction
aerial photography (vertical and oblique)
field walking survey
large scale continuous geophysical survey
historical maps
Documentary sources
mapping archaeology
archaeological excavation
LiDAR
Satellite Imagery

Introduction

past/present

only detected by aerial photography
only detected by multi-spectral imagery
only detected by fluxgate gradiometer
detected by more than one method

Introduction

past/present
Over the past ten years have been developed many innovative technologies in remote sensing. The leading news and most significant advances (from the archaeological perspective) have been achieved from my point of view in the following macro areas:

- Satellite
- LIDAR
- UAV
- Geophysics

In absolute terms, all this tools are likely to be effective although it should be noted that not all macro-areas have the same level of impact in the increase of archaeological process.
Various basic levels of scale have been recognized in archaeology:


Butzer (1982) proposed a more detailed graduation of scales, including ‘mid-scale’.

However, no one scale that is better than the others; the key point is that it is the purpose of the mapping that should determine its scale.

In topographical mapping, for example, an increase in detail involves the revision or supplementing of the contour lines and spot heights.

In this case the difference of scale does not affect the strategy of work in any substantial way, nor the technical means or basic methodology for achieving it.

The archaeologist who has to cope with the transition to a more detailed scale must, however, give thought to the availability or introduction of instruments that are barely applicable today at the smaller scale.
Archaeological research and the issue of scale of detail

‘MACRO’ SCALE – it is the higher scale, depending for its support most of all on literary, bibliographical and documentary sources, on place name, iconography, epigraphy, historical cartography, aerial photography, SATELLITE IMAGERY.

‘MICRO’ SCALE – it is the smaller scale, traditionally concerned with archaeological excavation; in the past decade, however, it has also drawn heavily on the contribution of GEOPHYSICS and UAV.

‘LOCAL’ SCALE, a term used here to indicate the shadowy zone between micro- and macro scale. I believe that currently AIRBORNE LIDAR and LARGE SCALE GEOPHYSICS represent the most innovative methodologies to explore that level of scale.
Over the past fifteen years, the resolution of the satellites increased from 20 m/pixel (Spot) to 0.40 m/pixel (GeoEye1) which represents an increase of about 2500 times.

The opportunities of application are therefore greatly increased although there are still some significant limitations including:

- DATA CAPTURE SCHEDULING
- SPECTRAL RESOLUTION
- GEOMETRIC RESOLUTION

From the prospective of a European observer wandering through a library, might be forgiven for believing that satellite remote sensing is the prime application for archaeological remote sensing.

This is of course not the case in Europe:

"FOR EVERY 'SITE' IDENTIFIED FROM SPACE THOUSANDS HAVE BEEN IDENTIFIED THROUGH AIR-PHOTOGRAPHY"
The outcome from the European perspective, in the practice of archaeological research, is the use of satellite imagery in absence of other data availability that today should be still often considered superior (quality, costs, results):

- aerial photography
- geophysical prospection
- LiDAR
- Airborne Multi-Spectral Scanner
- Airborne Iper-Spectral Scanner
In the 2003, at Gent University in Belgium Robert Bewley, then Head of English Heritage’s Aerial Survey Unit, argued that “…the introduction of LiDAR is probably the most significant development for archaeological remote sensing since the invention of photography” (Bewley, 2005).

Currently, the archaeological application of Lidar technology is growing quickly and the results are definitively exciting opening new perspective in the field of detection (with particular regard to under canopy and leveled landscapes) and monitoring archaeological evidence.
In the following years LiDAR applications have been developed widely around Europe and particularly in the UK, Austria, France, Germany, Norway and Italy.

Currently the principal advantage of LiDAR survey for archaeologists should be recognized in:

- **provide a high-resolution DEM revealing micro-topography** which is virtually indistinguishable at ground level.
- **Removal of trees** so as to produce an under canopy DTM.
LiDAR
Sample 523 km²
Siena 22 km²
Grosseto 501 km²
Resolution 1 pt/mq
New sites 97

LiDAR present
Helicopter based LiDAR FLI-MAP 400 (slower speed and lower flying), multiple return feature, combined with ultra high frequency enables:

- **Much higher resolution** up to 60 pts/m² (about 10 cm resolution);
- **Effective under-canopy visibility** also in the most densely vegetated areas;
- Very high resolution enable to record **micro-topographic element** even where the remains of archaeological sites are severely degraded.
• **Cost is the major determining factor BUT THE VALUE** in terms of research and heritage management has been recognized.

• From our perspective the only reservation would be the **LIMITED AREA HAVE BEEN ABLE TO COVER** by this technique given the funding available and the **MASSIVE** amount of data collected per sq km.

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<th>Tara</th>
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<tr>
<td><strong>Survey area</strong></td>
<td>85km²</td>
<td>2.38km²</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>0.5m</td>
<td>0.1m</td>
</tr>
<tr>
<td><strong>Total No. Points</strong></td>
<td>85 Million</td>
<td>150 million</td>
</tr>
<tr>
<td><strong>Accuracy Z</strong></td>
<td>±7cm</td>
<td>±3cm</td>
</tr>
<tr>
<td><strong>Accuracy X, Y</strong></td>
<td>±15cm</td>
<td>±5cm</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td>Landscape</td>
<td>Monument</td>
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Unlike technologies we have discussed so far, the main aims of this kind of system is addressed at the diagnosis of very specific areas or more frequently to 2D and 3D documentation of archaeological excavation, archaeological park or monuments.

**UAV**

Commercial UAV are also currently available. My lab i.e. in collaboration with FBK foundation and Zenit started a project – ArcheoDRONE project - with to develop a semi-automatic system to achieve stereo pairs addressed produce a 3D documentation of archaeological excavation.
The project started in summer 2007 when we did the first test on archaeological excavation. On this occasion several limits have emerged:

- lack of experience of piloting and in the evaluation of field conditions
- heavy dependence by wind condition
- poor reliability of the system
- take-off weight allowing only compact camera
- Difficult to extract metric data from compact camera
The availability of a **more advanced UAV system** (MD4-1000 microdrones [http://www.microdrones.com](http://www.microdrones.com)) allows using:

- **full frame reflex camera**, 
- **flight time** up to 70 minutes (dep. on load/wind /battery)
- **operate in a more wide range of environmental conditions**

<table>
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<th>Parameter</th>
<th>Specification</th>
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<tr>
<td>temperature</td>
<td>0-40 °C</td>
</tr>
<tr>
<td>humidity max.</td>
<td>80%</td>
</tr>
<tr>
<td>wind tolerance</td>
<td>steady pictures</td>
</tr>
<tr>
<td>flight radius</td>
<td>up to 6m/s</td>
</tr>
<tr>
<td>Cooperating altitude</td>
<td>up to 1000m</td>
</tr>
<tr>
<td>take-off altitude</td>
<td>up to 4000m above sea</td>
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**UAV future geophysics**
Over the past ten years we have seen a major improvement of all key-geophysical instruments commonly applied to archeological research. More sensitive and faster resistivity meter and magnetometer, multi-channel radar, however, in our opinion it happens in that period three most significant changes:

- **Direct involvement of archaeologists** in the management of geophysical data from data collection to the interpretation
- Extending survey from site to “off-site” and landscape: the discovery of the *archaeological continuum*
- Development of new system aimed to collect large scale data

In the Vale of Pickering, North Yorkshire, England, The Landscape Research Centre has been engaged in remote sensing since the mid 1970’s, focused upon a single landscape employing conventional air photography, airborne multi-spectral and hyper-spectral scanners, Lidar and ground based geophysics and other ground based surveys in addition to about 30Ha of open area excavation.
Veio (Italy): abandoned Etruscan and Roman City about 100 ha.

Landscape around the Roman city of Roselle in Tuscan countryside. We selected a sample area of about 1000 ha, which has been explored 185 ha.
In the past geophysical prospection has been used to get information about relatively small areas. Most of archaeological survey cover about 1 or 2 ha notwithstanding sometimes has been surveyed larger areas.

However a common trend is to investigate only archaeological areas. Archaeologists don’t survey off-site.

Time has progressed changes in geophysics. Gradiometers, resistivity meters and GPR can achieve in a day to around three hectares.

The area covered could be greatly enhanced by constructing a new cart or trolley that could be pulled by a quad bike;
Automatic Resistivity Profiler - ARP©
geophysics present/future

geophysics present/future
Empuries (Girona – Spain)

Vieil-Evreux (France)

g e o p h y s i c s
p re s e n t
NOW IT'S POSSIBLE TO APPLY GEOPHYSICAL PROSPECTION ON VERY LARGE SCALE IN A VERY SHORT TIME

THAT'S A SCALE JUMP FROM SITE-SCALE TO LANDSCAPE-SCALE
That’s a real innovation!

A real change in the practice and theory of archaeological process ... perhaps we could define this approach as a “revolution” in archaeology with consequence over at least:

- CONSERVATION
- ARCHAEOLOGICAL ISSUES
- THE FUTURE

Final remarks
From this short presentation I hope it is clear how remote sensing is progressively increased from an aseptic instrument aimed at documentation, to an original methodology very effective for the identification of archaeological sites, to become currently in the most advanced case histories the key to overcome an outdated approach to archaeological research and conservation, focuses on site and then on find.

It should be recognized that currently WITHOUT INCLUDING REMOTE SENSING IN THE FRAMEWORK OF ARCHAEOLOGICAL RESEARCH it is not possible to explore large sites and landscape in its complexity.

**final remarks**

need of data integration

only detected by aerial photography
only detected by multi-spectral imagery
only detected by fluxgate gradiometer
detected by more than one method
BUT ... WE ALSO Need integration of skills, experience and aims

1. Associations
   Aerial Archaeology Research Group (AARG): http://www.univie.ac.at/aarg
   International Society for Archaeological Prospection: http://www.brad.ac.uk/archsci/archprospection/
   ...

2. Universities and research centers

3. Networking remote sensing in archaeology
   (Archeolandscapes EU project)

final remarks

thank you for your attention

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