Remote Sensing and Digital Image Processing

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Satellite Remote Sensing

A New Tool for Archaeology

Springer

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Cover illustration: "with courtesy of Rio Nasca (Peru): discovery of a buried settlement with pyramid discovered by the processing of QuickBird-2 imagery"

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Foreword

In 2008 I was asked by Rosa Lasaponara and Nicola Masini whether the European Space Agency could support a workshop on the use of remote sensing for archaeology. We decided to do that and this gave a platform to sum up the state of the art in this area. Meanwhile the area has developed and it was time to produce a book which introduces the new methods to a broader community.

Nowadays the quantity and quality of information about the surface of the Earth obtained remotely is increasing at an ever faster rate. In the beginning of the twentieth century, photos were taken from hot air balloons. In the 1970s, multispectral sensors were put into orbit, followed by spaceborne imaging radar (SAR) and airborne LIDAR. In the last decades we have seen remote sensing technology pushing the boundaries of all fronts. Instruments are acquiring data at higher spatial resolution, broader spectral ranges, more radar frequency bands and wave polarisations. Processing techniques are constantly evolving with increasing computing power.

Technological developments in satellite remote sensing have rarely been driven by archaeologists. The instruments they use on the ground for their field surveys, such as magnetometers and ground penetrating radars, were initially developed for geological and civil engineering purposes. In a similar way, the science of remote sensing has largely been shaped by other disciplines. However, the benefits of satellite remote sensing to archaeologists have been quickly recognised. Remote sensing is now an essential tool for a range of different archaeological domains.

The creativity of archaeologists worldwide in using remote sensing for subsurface archaeological feature detection and analysis of the palaeo-environment has been demonstrated in many cases. Crop and soil marks have been identified on air photos, and shadow effects on oblique photos highlight topographical effects potentially caused by buried structures. LIDAR provides evidence of subsurface structures hidden under the forest canopy, by mapping subtle changes in relief at very high resolution. The sensitivity of near infrared radiation to vegetation has greatly enhanced the ability to identify crop marks. SAR images have led to the discovery of ancient roads leading to lost cities through the analysis of linear features. The same type of imagery, at long wavelengths, have given archaeologists clues to the location of formerly inhabited sites with the discovery of ancient river beds beneath the sand of the Sahara. The combination of multispectral image analysis to identify the spectral signature of tropical vegetation growing over buried structures, together with DEM analysis of the canopy topography has lead to the identification of many sites in rainforest regions. Buried archaeological features have been identified on thermal infrared satellite imagery, most notably in Egypt with a remarkable recent discovery of many sites.

The main benefit of remote sensing to managers of cultural heritage sites is due to the fact that instruments are regularly acquiring data onboard satellites continuously orbiting the Earth. Cultural heritage sites require regular monitoring of any potential degradation, looting and changes to the surrounding environment that may threaten their safety. For the many sites which are in inaccessible places satellite remote sensing is the only feasible tool for such monitoring. Remote sensing will be increasingly used with the launch of more satellites, easier access to data, and a greater archive of data becoming available for the analysis of changes over time, many of which are very gradual.

The application of remote sensing to archaeology has also included the use of classical data processing methods, such as image enhancement, edge detection, vegetation indices and principle components analysis. GIS is becoming a means to manage the ever larger volumes of data required for archaeological analysis and cultural heritage documentation.

It is important to acknowledge that limitations do exist, be it in the spatial resolution, the spectral characteristics, or in the availability of data for the requested season or time of day. As the momentum of progress continues, these limitations will be increasingly overcome. In the meantime, archaeologists do the best they can with what is available to them, and what they are able to achieve is impressive indeed.

This book gives an overview of different remote sensing methods of optical satellite data. I hope the systematic overview found in the book will foster the wider utilisation of remote sensing methods for archaeology and for the documentation and monitoring of our cultural heritage. Living myself in a country where archaeological sites are found everywhere the latter seems especially important seeing the fast rate of change in our environment.

Volker Liebig

Foreword

In 2008 the editors of this volume, also authors of the first methodological section and three chapters on case studies, organized the 1st EARSeL International Workshop on Advances in Remote Sensing for Archaeology and Cultural Management convened by the Italian National Research Council (CNR) and UNESCO in Rome and sponsored by the European Space Agency (ESA), Italian Space Agency (ASI), Belgian Science Policy (BELSPO), and Geocart srl.

NASA had an interest as well, as 2007 marked the release of the first NASA opportunity in Space Archaeology. Building on the success of the workshop, several Archaeology sessions were sponsored at the following annual European Association of Remote Sensing Laboratories (EARSeL) Symposium with particular reference to the event held at UNESCO Headquarters (Paris) in 2010.

Throughout the workshop and conference sessions, it was remarkable to see how Geographic Information Systems (GIS) have allowed a fusion of remote sensing and other geographic data with traditional field-based techniques. Even so, it was clear that the application of remote sensing techniques to archaeology was at a very early stage, similar to its early development in geology.

One aspect of these early stages of development is an apparent dichotomy between detailed site-based studies, generally using geophysical techniques to supplement traditional field-based excavations vs. context or prospection applications, which use broader coverage to provide a context to the site-based work and to seek new sites through surveys. Site-based studies focus on low-altitude airborne (or kite and balloon) photography, often oblique, to map subtle surficial indicators while field geophysical techniques such as ground penetrating radar (GPR) and other electromagnetic techniques are used to probe the subsurface in a very limited area in conjunction with traditional surface mapping of the site. Usually these techniques are employed at known sites.

Context or prospection applications represent some of the newer applications of remote sensing techniques, which tend to be lower resolution and hence unfit for detailed site characterization. Studies presented here show how satellite remote sensing can be used to characterize landscapes in a region, allowing prediction of occupation sites or transportation pathways. Airborne multi-sensor remote sensing (as distinguished from air photography) produces better resolution than satellites, but is more costly so is not being used extensively.

One promising remote sensing technique that could bridge the gap between prospection and detailed site characterization is airborne LiDAR. This technique provides highly detailed topographic data (less than 1 m spatial resolution) over large areas. Another 'cross-over' technique discussed in this volume is very high resolution (VHR) satellite images. These may be used to replace air photography.

Both airborne photography and remote sensing techniques suffer from a plethora of possible data-collection possibilities. For both, season and time of day create variations in shadowing, soil moisture, vegetation stress, snow cover, etc. that affect the visibility of the subtle marks betraying buried archaeological sites. In addition, remote sensing techniques range the entire electromagnetic spectrum from ultraviolet to microwaves along with many possibilities for processing to bring out the subtle remote sensing signatures of archaeological remains. This wide variety of possibilities is one reason more traditional archaeologists haven't embraced remote sensing techniques. However, some studies show the possibility of convergence toward more 'popular' spectral bands, seasons, and processing techniques. It is possible that the community may be able to simplify these choices to a set of easily implemented techniques which could be included in image-processing packages. Simplifying the choices of remote sensing acquisitions will also reduce the cost of acquiring many scenes of the same site at different times.

As the papers in this volume and those presented at the past workshop and conferences show, this is an exciting time in the application of remote sensing techniques to archaeology. Much progress has been made, but many dimensions remain to be explored.

Pasadena, CA, USA Tom G. Farr

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Special thanks to:

Rudi Goossens former EARSeL Chairman who strongly encouraged the proposal and all the activities of the Re.Se.Ar.C.H SIG mainly focused on fostering interaction among archaeologists, remote sensing researchers and managers interested in the use of remote sensing data (from ground, aerial and satellite) and Information Technologies to improve traditional approach for archaeological investigation, protection and management of natural and cultural heritage;

Rainer Reuter EARSeL Chairman who encouraged and supported this book inside the framework of Springer Series on Remote Sensing and Digital Image Processing and for promoting a strong and profitable interaction among archaeologists and remote sensing community.

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Tito Scalo, PZ, Italy

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Introduction

The importance of applying satellite remote sensing as a non destructive tool to uncover remains of ancient human occupation and past archaeological landscapes has been highlighted by national and international space agencies such as Nasa and ESA, promoted by UNESCO and now recognized by archaeologists and remote sensing scientific community. In this exciting cultural framework and in collaboration with UNESCO, in June 2007 EARSeL launched the Special Interest Group (SIG) on Remote Sensing for Archaeology, Natural and Cultural Heritage (Re.Se.Ar.C.H.) chaired by Rosa Lasaponara, Nicola Masini from CNR, and Mario Hernadez from UNESCO. Over the years the Re.Se.Ar.C.H SIG organized international conferences and workshops on the topic of "archaeology from space" to explore the emerging capability and strategic challenges in this field.

During these years two books approached this topic, one by Wiseman and Farouk (2007), mainly focused on the use of satellite radar data, and the other is a handbook on "a survey of the history and development of the field" (Parcak 2009).

"Satellite Remote Sensing: A New Tool for Archaeology" book is the first comprehensive overview of "optical" satellite remote sensing for archaeology focused on both methodological approaches and practical applications, obtained as result from a long and intense cooperation between archaeologists and remote sensing community. This cooperation provided vital lymph to compare diverse needs, perspectives and thinking very useful to go on the emerging capability of remote sensing archaeology and face new strategic challenges to preserve the past for the future.

This feeling is in this volume which is harmonically organized to deal with advanced technological/methodological developments and practical results obtained in archaeological projects and palaeo-environmental studies.

The book is divided into three sections, grouping chapters dealing with similar topics.

The first section (by Lasaponara and Masini) divided in four chapters focuses on technical developments and provides a resumel of the elaboration and computational strategies which may be suitable exploited for practical uses of satellite remote sensing in archaeology spanning from discovery of unknown sites, to documentation, management and site preservation, facing natural and anthropogenic risks such as agricultural mechanization, looting, pollution and conflict/war devastations.

In particular the first chapter provides a brief overview on qualitative and quantitative data analysis from visual interpretation to digital manipulation. In the following chapter image enhancement and features extraction methodologies along with geospatial analysis have been discussed in an archaeological perspective. Chapter 3 deals with the methods and the potential of classification and pattern recognition using satellite data for archaeological purposes. The first section ends with an overview of pan-sharpening techniques and quantitative evaluation of their capability in preserving spectral fidelity and spatial and textural content associated to archaeological information.

The second is focused on the use of Satellite Remote Sensing to support the survey, documentation and management of cultural resources.

The third part explores the potentiality of VHR satellite remote sensing data for recording ancient features as new invaluable tools in archaeological projects and palaeo-environmental studies.

Magnificent and highly significant case studies are presented and discussed, selected from within Europe, Asia, South America, and the Middle East including Hierapolis in Phrigia, Nasca (Peru), Angkor (Cambodia), Jabali silver mines (Yemen), Sri Ksetra (Central Burma), Dobrogea (Romania), Arge-Bam (Iran).

In particular Bitelli G. reviewed some of the issues related to Satellite Remote Sensing and Geomatics in the archaeological context. Moreover, a risk management application in the Arge-Bam Citadel, south-eastern Iran, based on object-oriented approach has been presented.

The reconstruction of the urban fabric of Hierapolis and the study of the ancient topography of its territory by means of the integration of VHR satellite data, declassified satellite photos, field works and other ancillary information is described by Scardozzi G.

Marco Giardino provides an overview of NASA experience in the field of aerial and satellite remote sensing in Archaeology. The chapter include the some projects such as the identification of prehistoric roads in Chaco canyon and prehistoric settlement patterns in southeast Louisiana, the Coast 2050 Cultural Resources Survey, the Lewis and Clark Expedition project.

In Chap. 8, a method based on geostatistics and satellite remote sensing for the assessment of archaeological looting is proposed by Lasaponara et al. The rate of success of such method has been computed test site is in Cahuachi near Nasca (Peru), thus providing satisfactory results.

Evans and Traviglia within the Greater Angkor Project provide important information on the rise and fall of medieval urbanism at Angkor, in Cambodia, by extensive use of remotely sensed imagery which allowed to find, map and analyse elements of urban form. In particular, the authors focused on the role of Angkor's water management system and on human modifications to the natural hydrology and topography in the demise of the urban complex.

Deroin et al shows the results of a multidisciplinary research, based on the use of satellite remote sensing applied to mining archaeology. The ALOS-AVNIR-2 data along with QuickBird images have been fruitfully used for the teleanalytical geological mapping of the ancient Jabali silver mines in northern Yemen.

The chapter by Stargardt et al. documents the sub-surface and surface movement of moisture after the end of the monsoon season, across the urban site of Sri Ksetra, on the southern edge of the Dry Zone of Central Burma. Multi-spectral and multi-temporal satellite imagery reveal how surface and sub-surface water still flows along the ancient irrigation channels whose study is crucial for the analysis of urban development of Sri Ksetra founded by the Pyu people, ca. fourth century AD.

In Chap. 12 by Lasaponara and Masini, Landsat and ASTER data have been analyzed for some areas near Nasca river within the drainage basin of the Rio Grande (Peru), densely settled over the centuries and millennia even if the physical environment presented serious obstacles to human occupation. The results allowed to identify areas for further investigations aimed at detecting ancient underground aqueducts called puquios which were constructed for water control and retrieval during the Nasca age.

Oltean and Abell perform a comparative analysis of a rich aerial and satellite dataset, including declassified images, in order to discuss the potential of satellite imagery to reveal buried archaeological features in the area of southern Dobrogea (Romania) and to assist in the reconstruction of past landscapes. It outlines some of the methodological approaches employed, highlights areas for further research and presents some preliminary outcomes.

Finally, Masini et al showed the archaeogeophysical approach of ITACA Mission based on the use of satellite and ground remote sensing and the results obtained in the Ceremonial Center of Cahuachi, near Nasca (Peru). In particular a large buried settlement characterized by a pyramid has been detected in the Nasca riverbed as well as tombs and ritual offerings have been identified and unearthed by archaeologists in Piramide Naranjada.

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