Silk Road Project: remote sensing for a smart management of cultural heritage from site detection to monitoring and documentation

N. Masini (1); R. Lasaponara (2); F. Chen (3,4)

(1) IBAM-Istituto per i Beni Archeologici e Monumentali, CNR, Tito Scalo (PZ), Italy (n.masini@ibam.cnr.it, ++390971427333),
(2) CNR-IMAA, Tito, Italy
(3) Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing, China,
(4) International Centre on Space Technologies for Natural and Cultural Heritage under the Auspices of UNESCO, Beijing, China,
The use of Earth Observation (EO) technologies and ICT in Archaeology has been strongly increasing during the last twenty years.

**Technological reasons**
- improvement of spectral and spatial resolution of (airborne/satellite) sensors;
- availability of user-friendly and low cost softwares/tools for data acquisition, analysis and processing

**Cultural reasons**
- awareness of archaeologists of the benefits of EO
  - reduction of costs, time and risk associated with archeological excavations;
  - creation of site strategies addressed to conservation and preservation
- the interests of archaeologists to study the dynamics of human frequentation in relation to environmental changes;
- Multipurpose needs (including monitoring)
Earth Observation and ICT for Archaeology: Debate issues and topics

- How select the most appropriate technology and methodology?
- Is the technological potential of EO exploited for CH and Archaeology?
- How manage costs, time, information content?
- Which is the added value of active data (LiDAR and SAR)
- Do user friendly and/or low cost affect the quality of information content for Cultural Heritage application?

Project of Great Relevance Italy-China on Earth Observation (EO) and ICT for Cultural Heritage (CH) management
Title: Smart management of cultural heritage sites in Italy and China: Earth Observation and pilot projects

Partnership:
Italy: CNR/IBAM, CNR/IMAA
China: RADI and HIST (CAS), ZhengZhou University

Scientific responsible
Nicola Masini (CNR/IBAM) and Fulong Chen (RADI/HIST)
WHY the ITALIAN an CHINESE scientific cooperation?

the extraordinary cultural heritage witnesses of ancient civilizations in both countries

Rome, Coliseum

Beijing, Prohibited city
**Common** Italian and Chinese interests in obtaining advances, operative tools and technologies for the protection and enhancement of cultural heritage with particular reference to sites included in the UNESCO list.

**Complementary expertises** of Italian and Chinese researchers involved in project

the opportunity to **share** and use remote sensing data (satellite, aerial, etc..)
AIMS OF THE PROJECT

- Achieve advances in knowledge, methods and technologies
- to support and facilitate a smart management of cultural sites which require constant monitoring activities to preserve their integrity.

HOW?

- Pilot studies
  - China: Silk road, Luoyang, Longmen, HongCun
  - Italy: Rome, medieval landscape in Southern Italy, Pompeii
- Sharing data, tools, practises and experiences
  - Virtual Laboratory “Silk Road Cloud” Researcher exchange
Case studies and project pilots in China

- Detection of ancient abandoned/buried roads and settlements along the Silk road in Xinjiang region
- Assessment of SAR data capability in detecting buried archaeological sites in arid and desertic setting and microrelief for any surface and environmental characteristics
- Ancient China underneath: the big challenge of archaeogeophysics in Henan
- Ancient Chinese landscapes disappeared: multitemporal remote sensing observation
- EO and ICT for 3d smart management and documentation of world heritage monuments, sites and artifacts (HongCun, Longmen)
The Silk Road, a series of trade and cultural transmission routes connecting China to Europe, is witness to a civilization friendship and harmony between the East and West dating back 2000 years, that has left us with various relics (e.g. lost cities) to be uncovered and investigated.
The challenge in Henan: which geophysical and remote sensing approach to detect buried remains of Luoyang capital?
The challenge in Henan: which geophysical and remote sensing approach to detect buried remains of Luoyang capital?

Shadow, crop, soil and damp archaeological marks observed on processed COSMO-SkyMed SAR imagery. (a) Shadow mark, (b) crop marks, and (c) soil and damp marks
The challenge in Dingding gate: which geophysical approach to detect buried remains of Luoyang capital?
Assessment of SAR data capability in detecting buried archaeological sites
The case of Niya: the Chinese Pompeii
Project pilot in China: Revealing ancient landscapes in China

1958 Aerial photo

1969 Declassified satellite image
Image based 3d reconstruction of monuments and artifacts

Application on the Buddhas of Longmen
Italian case studies

Cisterna: Discovery and mapping of a medieval settlement

Pompeii: Integrated remote sensing and geophysical methods for structural diagnosis
USE OF SAR FOR THE DETECTION OF ANCIENT PALAEO CHANNELS/RIVERS: METAPONTO

Chen et al, 2014
USE OF SAR FOR THE DETECTION OF ANCIENT PALAEO CHANNELS/RIVERS: METAPONTO

Chen et al., 2014
Cisterna: Discovery and mapping of a medieval fortified settlement

Location
Northern area of Basilicata near Melfi

What did we know
- The existence of a medieval village named Cisterna and a castle from medieval documentary sources (12-13° century)
- In the 12° Cisterna was seat of a diocesis
- It is abandoned after the 15° century
- Maps of the 17° century refer the presence of a castle-tower

Expected information from remote Sensing
- Identification, mapping of the medieval settlement including a castle
Cisterna: integrated remote sensing approach

Aerial orthophoto

Aerial Infrared thermography

DTM provided from LiDAR survey
Airborne Laser Scanner (ASL) or LiDAR (Light Detection And Ranging)

- It provides direct range measurements mapped into 3D point clouds between a laser scanner and earth’s topography.

- The laser scanner, mounted to an aeroplane or helicopter, emits near infrared pulses, at a frequency rate of **30,000 to 100,000** pulses per second, into different directions along the flight path towards the terrain surface.

- Each pulse could be reflected one or more times from objects (ground surface, vegetation, buildings, etc.), whose position is determined by computing
  - the **time delay** between emission and each received echo,
  - the **angle** of the emitted laser beam,
  - the **position** of the scanner (determined using differential global positioning system and an inertial measurement unit).

Available scanners

- **conventional** scanners or **discrete** echo scanners delivers only the first and last echo, thus losing many other reflections

- **full-waveform** (FW) scanners detects the entire echo waveform for each emitted laser beam*.
Digital Terrain Model (DTMs) are obtained by the discrimination of on-terrain from off-terrain points (Classification) by using the diverse laser measurements:
(i) height; (ii) intensity; (iii) echo width

The elimination of outliers points is performed through classification of:

- **“low points”**
  - single points or groups of points with an height lower than 0.5 m compared the other points within a ray of 5 m
- **“air points.”**
  - points present in the air (i.e. birds, etc.).
- **isolated points**
  - points present in the air not classified as airpoints.
Cisterna: Discovery and mapping of a medieval fortified settlement

Cisterna: Aerial Orthophoto – Visible spectrum
Cisterna: Discovery and mapping of a medieval fortified settlement
Cisterna: Discovery and mapping of a medieval fortified settlement
Vegetation filtering

Tower

walls
A: castle
B: tower
C: urban walls

Hill shading

Altitude: 70°
Azimuth: 90°/180°
Slope kernel size (ks) = 3

Slope (ks=5)

Maximum curvature
ks=5

Profile convexity (ks=3)

Profile convexity (ks=6)
Regio VIII in the archaeological area of Pompeii

The Regio VIII, occupies the south-western sector of the city. It is bounded (at South) by an irregular stretch of city walls between the two gates Porta Stabia and Porta Marina.

Regio VIII has a urban layout rather irregular, especially along the southern border, having to adapt to the edge of the lava outcrop on which the city stands.

Chronology
**End of the 7th - late 4th century BC**: Casa dei Postumii; Doric temple of the Triangular Forum (half of the sixth century BC); **3rd – 2nd century**: Great Theatre and Quadriportico o Caserma dei Gladiatori, Basilica; **1st cent BC-1st cent AD**: Odeion or Theatre Hall, restructuring of the domus with atrium built against the city walls on the southern slopes.
Regio VIII in the archaeological area of Pompeii: some investigated area

Regio VIII: detail of insula 1,1: (Basilica)

Insula 2, 13: domus

Triangula Forum: columns

Insula 2, 21: domus of L. Aelius Magnus
A) Masonry structures: investigation of building techniques, decay patterns (cracks, inhomogeneities, voids), survey of deformations

B) Frescoes: detection of detachments and inhomogeneities

C) Wells and cisterns: exploration and survey
Methodological approach

3d reconstruction of masonry structure geometry and deformations

3d-model provided from UAV-based survey

Video endoscopy

Validation with direct data

GPR, Sonic and (in case) infrared thermography data integration for the detection of building and decay features
Pompei, Regio VIII: Basilica
Building techniques:
The wall is made by irregular stone elements of Peperino with thickness equal to approximately 0.66 m. It is a wall at multiple body consisting of three layers (15+30+15 cm), of which the central one very well joined with the two adjacent. Layers of plaster of thickness varying from 3 to 7 cm, on both sides of the wall.
The data analysis showed the presence: of a number of defects attributable to the discontinuity (D) which are much more evident in the lower part (see Profile R1); the layer of plaster (I - yellow dashed line) of variable thickness between 1 and 3cm.
Discontinuities between the external layer and the inner nucleus

Georadar time slice at 18-23 cm depth

Georadar time slice at 46-51 cm depth

Sonic tomography at 25 cm depth

Sonic tomography at 45 cm depth
Per l'indagine delle colonne 1 e 2 sono stati acquisiti 5 profili di cui 3 longitudinali (R1, R2, R3) e 2 trasversali (R4, R5). A causa dell'esistenza di strutture di cattura è stata possibile indagare le colonne fino ad un'altezza massima di 9,20 m. Per l'indagine delle colonne 3, a causa della presenza di strutture di rinforzo in ferro, sono stati realizzati 2 profili longitudinali K1 ed K2.

Come di seguito mostrato negli elaborati grafici, sono state rilevate anomalie locali attribuibili principalmente a:
- discontinuità e/o vasi costruttivi localizzati
- fratture e/o lesioni

Per l'interpretazione delle anomalie ci è fatto riferimento ai radarogrammi ed alla stessa di ampiezza che mostrano il quarto delle anomalie presenti all'interno delle colonne alle diverse profondità.

Inoltre, la visualizzazione 3D delle superfici di tale ampiezza permette di individuare le discontinuità ed il degrado del paramento murario.
CONCLUSIONS

- Remote Sensing for Archaeology from the Italian and Chinese perspective: promising results for more operative uses
- The applications (from site discovery to risk monitoring) need to be interrelated
- New lines of research and activity
  - SAR data capability assessment for different environmental setting (from Mediterranean basing to desert)
  - Mapping and Study of ancient landscapes in China

FUTURE PERSPECTIVES

- Reinforce the scientific cooperation Italy-China on some pilot projects (Pompeii, Henan)
- Mapping abandoned routes of Silk Road
- Researchers exchange
- Establish the first archaeogepysical mission in Henan
- Creation of a Virtual Laboratory